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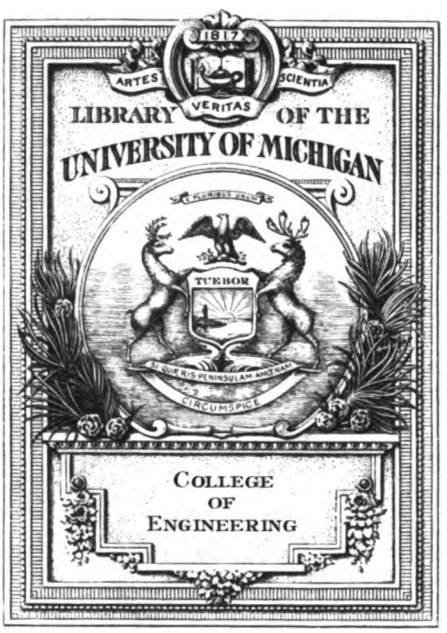

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Woodhouse, John T.
Woolley, Adam Sedgwick (Secretary).
Woolley, Joseph, M.A., LL.D., F.R.A.S. (Vice-President).
Wright, James, C.E.

Yelverton, Sir Hastings R., K.C.B., Vice-Admiral.
Yeo, John, Engineer, R.N.
Young, Charles F. T.
Young, William.

Zeysing, Theodore, Prussian Royal Navy.

Members and Associates whose Deaths have been notified to the Secretary since the issue of Vol. XV.

Campbell, F. A., Rear-Admiral (Associate).
Cunningham, H. D. P., R.N. (Associate).
Dudgeon William (Associate).
Fountaine, Andrew (Associate).
Laird, John, M.P. (Member and Vice-President).
Lloyd, Thomas, C.B. (Member and Vice-President).

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OBJECTS OF THE INSTITUTION.

The objects of the Institution of Naval Architects—which was established to promote the Improvement of Ships, and of all that specially appertains to them—are comprised under three heads:—

First, the bringing together of those results of experience which so many shipbuilders, marine engineers, naval officers, yachtsmen, and others acquire, independently of each other, in various parts of the country, and which, though almost valueless when unconnected, doubtless tend much to improve our navies when brought together in the printed Transactions of an Institution.

Secondly, the carrying out, by the collective agency of the Institution, of such experimental and other enquiries as may be deemed essential to the promotion of the science and art of shipbuilding, but are of too great magnitude for private persons to undertake individually.

Thirdly, the examination of new inventions, and the investigation of those professional questions which often arise, and were left undecided before the establishment of this Institution, because no public body to which professional reference could be made then existed.

BYE-LAWS AND REGULATIONS.

CONSTITUTION.

1. The Institution of Naval Architects shall consist of four classes, *viz.*, Members, Associates, Honorary Members, and Honorary Associates.

2. *Members.*—The Class of Members shall consist exclusively of Naval Architects and Marine Engineers conversant with Naval Architecture.

3. *Associates.*—The Class of Associates shall consist of persons who are qualified, either by profession or occupation, or by scientific or other attainments, to discuss with Naval Architects the qualities of a ship, or the construction, manufacture, or arrangement of some part or parts of a ship or her equipment.

4. *Honorary Members.*—The Class of Honorary Members shall consist of persons who are eligible as Members, and upon whom the Council may see fit to confer an honorary distinction.

5. *Honorary Associates.*—The Class of Honorary Associates shall consist of persons who have contributed to the improvement of ships or their equipment, and upon whom the Council may see fit to confer an honorary distinction.

ELECTION AND DUTIES OF OFFICERS.

6. The Officers of the Institution shall consist of a President, Vice-Presidents, Members of Council, Associate Members of Council (not exceeding in number one-third the number of Members of Council), a Treasurer, two Auditors of Accounts, and a Secretary or Secretaries.

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7. A General Meeting of the Members and Associates of the Institution shall be held annually; and at this Annual General Meeting the Members of Council, Associate Members of Council, Treasurer, and Auditors for the ensuing year shall be elected.

8. At the Annual General Meeting Members only shall vote in the Election of Members of Council, and both Associates and Members in the Election of Associate Members of Council, the Treasurer and the Auditors.

9. As soon as may be convenient after the Annual General Meeting, the newly-elected Members and Associate Members of Council shall meet and elect the President and Vice-Presidents for the year, Members and Associate Members of Council both voting.

10. *President.*—Both Members and Associates of the Institution shall be eligible for election as President. The President shall preside over all Meetings of the Institution, and of Officers of the Institution, at which he is present, and shall regulate and keep order in the proceedings.

11. *Vice-Presidents.*—Both Members and Associates of the Institution shall be eligible for election as Vice-Presidents. In the absence of the President, one of the Vice-Presidents shall preside at the General Meetings of the Institution, and shall regulate and keep order in the proceedings.

12. In case of the absence of the President and of all the Vice-Presidents, the Meeting may elect any Member of Council or Associate Member of Council, and in case of their absence any Member present, to preside.

13. The Chairman at any Meeting of the Council or of the Institution, when the votes of the Meeting, including his own, are equally divided, shall be entitled to give a casting vote.

14. Persons holding the office of Vice-President shall at all times be entitled to sit and vote with the Council.

15. *Past Presidents and Vice-Presidents.*—All Members who have held the posts of President and Vice-President shall, while their connection with the Institution as Members lasts, be entitled to sit and vote with the Members of Council.

16. *Members of Council.*—Members only shall be eligible for Election as Members of Council at the Annual General Meeting.

17. *Associate Members of Council.*—Associates only shall be eligible for Election as Associate Members of Council at the Annual General Meeting.

18. The Direction and Management of the Institution shall be vested in the Council for the time being, the Associate Members voting with the Members of Council in all cases, except in the decision of questions directly affecting the forms of ships and the construction of their hulls.

19. The Council shall meet as often as the business of the Institution requires, and at every Meeting five Members of Council shall form a *quorum.*

20. The Council may appoint Committees to report to them upon special subjects.

21. All questions shall be decided in the Council by vote; but at the desire, expressed in writing, of any four Members or Associate Members present, the determination of any subject shall be postponed to the succeeding Meeting of the Council.

22. An annual statement of the funds of the Institution, and of the receipts and payments of the past year, shall be made under the direction of the Council, and after having been verified and signed by the Auditors, shall be laid before the Annual General Meeting.

23. The Council shall draw up an Annual Report on the state of the Institution, which shall be read at the Annual General Meeting.

24. It shall be the duty of the Council to adopt every possible means of advancing the Institution, to provide

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for properly conducting its business in all cases of emergency, such as the death or resignation of Officers, and to arrange for the publication of the Papers read at the Meetings, or of such documents as may be calculated to advance the objects of the Institution.

25. *Treasurer.*—Only Bankers, or Members of Council, or persons who have been Members of Council, and are still Members of the Institution, shall be eligible for election as Treasurer.

26. *Auditors.*—All Members and Associates of the Institution shall be eligible for election as Auditors.

27. The Auditors shall have access at all reasonable times to the Accounts of the pecuniary transactions of the Institution; and they shall examine and sign the annual statement of the Accounts before it is submitted by the Council to the Annual General Meeting.

28. *Secretary.*—The Secretary or Secretaries shall be elected by the Council, and shall be removable at the will of the Council, after due notice given. The salary of the Secretary or Secretaries shall be fixed by the Council.

29. It shall be the duty of the Secretary, under the direction of the Council, to conduct the correspondence of the Institution; to attend all Meetings of the Institution and of the Council; to take Minutes of the proceedings of such Meetings; to read the Minutes of the preceding Meeting; to announce donations made to the Institution; to superintend the publication of such Papers as the Council may direct; to have charge of the library, museum, and offices of the Institution; and to direct the collection of subscriptions and the preparation of accounts. He shall also engage, and be responsible for, all persons employed under him, and generally conduct the ordinary business of the Institution.

DESIGNATION OF MEMBERS AND ASSOCIATES.

30. Any Member, Associate, Honorary Member, or Honorary Associate, having occasion to designate himself as belonging to the Institution, shall state the class to which he belongs according to the following abbreviated forms, *viz.:* M.I.N.A.; Assoc. I.N.A.; Hon. Mem. I.N.A.; Hon. Assoc. I.N.A.

ELECTION OF MEMBERS AND ASSOCIATES.

31. *Admission of Members.*—Every Candidate for admission into the Class of Members, or for transfer into that Class from the Class of Associates, shall be more than twenty-five years of age, and shall comply with the following regulation:—

> He shall submit to the Council a statement, showing that he has been professionally engaged in shipbuilding or marine engineering for at least seven years in some public or private shipbuilding establishment, or marine engine works, and setting forth the grounds upon which he bases his claims to be considered a professional Naval Architect, or Marine Engineer, and to be admitted as such to the Membership of the Institution. This shall be signed by at least three Members, whose signatures shall certify their personal knowledge of the Candidate, and approval of his statement; or, in the case of persons not British born, the signatures of three Members shall be required, in confirmation of their personal knowledge of the Candidate's scientific reputation.

32. These preliminary conditions being satisfied, the Council shall then consider whether the practical experience and professional attainments of the Candidate are such as entitle him to be brought forward by the Council as a Naval Architect, or Marine Engineer conversant with Naval Architecture. If four-fifths at least of the received votes of the professional Members of the Council are in favour of his application, and such four-fifths constitute a majority of the professional Members of the Council, his proposal for admission shall be

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submitted to the Members of the Institution (who shall have access to the applicant's statement) at an Ordinary Meeting of the Institution, for them to vote upon, by ballot.

33. *Admission of Associates.*—Candidates for Associateship shall submit to the Council a proposal for their admission, setting forth therein a statement of their claims to be admitted as Associates. Their proposal, if approved by the Council, shall be submitted by them at an Ordinary Meeting of the Institution, for the Members and Associates jointly to vote upon by ballot.

34. The proportion of votes for deciding the election of Members and Associates shall be at least four-fifths of the numbers recorded.

SUBSCRIPTIONS.

35. Each Member and Associate shall pay an Annual Subscription of two guineas in advance; the first Subscription being payable on his election, and all future ones on the 1st day of January of each year. Any Member or Associate withdrawing from the Institution after that date is still liable for the amount of Subscription due on that day.

36. Any Member or Associate may compound for his Annual Subscription, for life, by a single payment of not less than thirty guineas.

MEETINGS.

37. Meetings for the Reading of Papers shall be held as frequently, and at such times, as the Council may determine.

TRANSACTIONS.

38. The *Transactions* of the Institution, including the Papers read at the Ordinary Meetings, and Reports of the Discussions by which they are followed, shall be edited by the Secretary, and printed under the direction of the Council.

39. A copy of each Volume of *Transactions* shall be sent free to every Member and Associate.

40. The Secretary, under the direction of the Council, may dispose of the surplus stock of *Transactions* which have been published more than three years, at a price of not less than One Guinea a Volume, provided a sufficient number remain on hand to supply the probable demand of new Members and Associates to complete their sets by the purchase of the back Volumes.

CHANGE OF ADDRESS.

41. Members and Associates are particularly requested to communicate to the Secretary any change of address.

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INTRODUCTORY PROCEEDINGS.

THE Meetings of this, the Sixteenth Session of the Institution of Naval Architects, were held on the 18th, 19th, and 20th March, 1875, in the Hall of the Society of Arts, John Street, Adelphi.

The opening Meeting was presided over by the Right Hon. LORD HAMPTON, G.C.B., D.C.L., President of the Institution, who commenced the proceedings by calling upon the Honorary Secretary, Mr. CHARLES W. MERRIFIELD, F.R.S., to read the Report of the Council, which was as follows:—

REPORT OF COUNCIL, MARCH 18TH, 1875.

" The Council of the Institution are glad to be able to report to the Members and Associates that the " financial prospects of the Institution are in a satisfactory condition.

" The Accounts now presented to you show that the balance to the credit of the Institution on the " 31st of December last was £352 10*s.* 6*d.*

" The liabilities up to the same date, which have since been discharged, amounted to £399 7*s.* 2*d.*; " but against this must be set the Grant of £250 from the Lords Commissioners of the Admiralty, which " did not arrive in time to appear in last year's accounts. A balance of £203 3*s.* 4*d.* is thus left to meet " future charges, irrespective of income received and expected during the current year.

" The Council desire to call the attention of the Members and Associates to the fact that the Classes " of the Royal Naval College at Greenwich, of which the School of Naval Architecture and Marine " Engineering now forms a part, are open not only to the Royal Navy and the Royal Dockyards, but also " to private Students. The Council earnestly hope that shipowners and builders, naval architects and " marine engineers, will not fail to give the full benefit of the advantages which the College affords to " those in whose professional education they have interest or responsibility.

" The Royal Commission on Unseaworthy Ships has presented its final Report. The chief features " of this Report, so far as they directly concern the naval architect, are negative. The Commissioners " do not recommend either an authoritative load line for ships, or a rule for their lading, and they do not " recommend any system of Government inspection during building, or any official recognition of the " existing Societies for the classification of ships. The Report contains many suggestions indirectly " affecting the interests both of shipbuilders and of shipowners; and as the merchant shipping is " now about to become the subject of legislation, the Council recommend these matters to the serious " consideration of its Members and Associates.

" A Bill is now before Parliament embodying the chief recommendations of the Royal Commission.

" The important question of tonnage, especially in its international bearing, was brought before " Parliament in the Session of 1874. A Bill on this subject was introduced into the House of Commons, " and was referred to a Select Committee. It did not become law, and it is understood that the " Government does not propose to introduce any measure on the subject this Session. The question " thus remains an open one for the present.

" The Council have to deplore the loss by death of two of their number—Mr. John Laird, M.P., " and Mr. Grantham—one Honorary Member, Sir William Fairbairn, and four Associates, *viz.*, Sir " Francis Pettit Smith, Mr. H. D. P. Cunningham, Mr. A. Fountaine, and Mr. A. A. Taylor."

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Institution of Naval Architects.

Statement of Income and Expenditure for the Year 1874.

Dr.

1873.	£	s.	d.	£	s.	d.
Dec. 31st. To Balance:—						
In Treasurer's hands	455	6	1			
In Assistant-Secretary's hands	57	16	7			
				513	2	8
1874.						
Dec. 31st. To Cash received:—						
Annual Subscriptions	761	10	7			
Volumes sold	15	14	5			
Rent from Canoe Club	21	13	4			
Sundry Receipts	0	11	3			
				799	9	7
				£1,312	12	3

Cr.

1874.	£	s.	d.	£	s.	d.
Dec. 31st. By Cash paid:—						
Rent of Rooms to 29th September, 1874	95	15	0			
Cleaning ditto to 28th December, 1874	16	4	6			
				111	19	6
Attendance at Meetings, 1874	12	8	0			
Reporting at ditto ...	30	0	0			
Abstract of Proceedings at ditto	43	10	0			
				85	18	0
Advertising, 1874				9	7	0
Printing Vol. XIV., and Miscellaneous Printing, 1873 ...	200	0	0			
Reducing Drawings, Vol. XV.	5	5	0			
Binding Vol. XIV. ...	29	19	6			
Copperplate Engraving, Vol. XIV.	43	10	7			
Distribution of Vol. XV. ...	19	4	5			
				297	19	6
Preparing Diagrams for Meeting, 1874				4	0	0
Stationery, 1873				12	2	9
Fire Insurance to 25th March, 1875				1	0	0
Banker's Charges				0	1	6
Petty Disbursements and Postages				58	12	11
Expenses of Library ...				8	14	3
Salary of Assistant-Secretary	293	10	0			
Ditto of Messenger	24	13	0			
Ditto of Occasional Clerk ...	24	18	4			
				343	1	4
Auditing Accounts				4	4	0
Expense of Removal to New Premises				23	1	0
By Balance:—						
In Treasurer's hands	332	13	1			
In Assistant-Secretary's hands	19	17	5			
				352	10	6
				£1,312	12	3

A. SEDGWICK WOOLLEY, *Assistant-Sec.*,
JOSEPH D'A. SAMUDA, *Treasurer.*

We have examined the above written entries with the books and vouchers, and find them correct.

ROBERT CARLYLE, }
JAMES MACKENZIE, } *Auditors.*

27th Feb., 1875.

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An Account of the State of the Funds of the Institution on 11th March, 1875, and of the Estimated Income and Expenditure for the Year 1875.

Dr.

	£	s.	d.	£	s.	d.
To Balance on 31st December, 1874 ...				352	10	6
„ Cash received:—						
Admiralty Grant, 1875	250	0	0			
Annual Subscriptions	226	15	11			
Volumes Sold	67	16	0			
Amount actually received				544	11	11
To Cash receivable:—						
Annual Subscriptions (say)	535	0	0			
Volumes Sold (say)	50	0	0			
Other Receipts (say)	21	0	0			
Admiralty Grant	250	0	0			
Estimated to be received				856	0	0
				£1,753	2	5

Cr.

	£	s.	d.	£	s.	d.
By Cash paid:—						
Rent of Rooms				25	0	0
Cleaning Rooms to 6th March, 1875				2	10	0
Printing Vol. XV., and Miscellaneous Printing, 1874				212	10	6
Salary of Assistant-Secretary (on account)	50	10	0			
Ditto of Messenger (on account) ...	5	0	0			
Extra Attendance (on account) ...	1	6	0			
				56	16	0
Copperplate Engraving, Vol. XV.				111	6	6
Wood Engraving, Vol. XV.				6	6	6
Lithography, Vol. XV.				3	10	0
Reducing Drawings, Vol. XV.				11	1	6
Binding Vol. XV.				32	7	2
Stationery				19	17	3
Postages and Petty Disbursements				9	10	10
Dispatch of Volume				0	11	0
Library Expenses				5	12	9
Advertising, 1873				1	8	7
Ditto, 1875				3	0	0
Amount actually paid ...				501	7	8
By Cash payable:—	£	s.	d.			
Rent and Cleaning, to 31st Dec., 1875 (say)	86	0	0			
Expenses of Annual Meeting (say) ...	85	0	0			
Salaries to 31st Dec., 1875	245	0	0			
Volume XVI. (every expense, say) ...	300	0	0			
Stationery (say)	12	0	0			
Furniture and Repairs (say)...	5	0	0			
Postages and Petty Disbursements (say)	50	0	0			
Library Expenses (say)	10	0	0			
Advertising (say)	36	0	0			
Fire Insurance	1	0	0			
Estimated Liabilities				830	0	0
Estimated Balance				421	14	9
				£1,753	2	5

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The following List of Donations to the Library of the Institution was then read by the Honorary Secretary:—

"Proceedings of the Royal Society of London," Vol. XXIII. *Presented by the Royal Society.*

"Minutes of the Proceedings of the Institution of Civil Engineers," Vols. XXXVII. and XXXVIII. *Presented by the Institution of Civil Engineers.*

"Proceedings of the Institution of Mechanical Engineers," for 1874. *Presented by the Institution of Mechanical Engineers.*

"Journal of the Iron and Steel Institute," for 1874. *Presented by the Iron and Steel Institute.*

"Journal of the Royal United Service Institution," for 1874. *Presented by the Royal United Service Institution.*

"Transactions of the Institution of Engineers in Scotland," Vol. XVII. *Presented by the Institution of Engineers in Scotland.*

"Transactions of the Royal Society of Victoria," Vol. X. *Presented by the Royal Society of Victoria.*

"The Engineer," for 1874. *Presented by the Proprietors.*

"Engineering," for 1874. *Presented by the Proprietors.*

"Iron," for 1874. *Presented by the Proprietors.*

"Annual Report of the Board of Regents of the Smithsonian Institution," for 1872. *Presented by the Board of Regents.*

"Naval Science," Vol. III. *Presented by the Proprietors.*

"Revue Maritime," for 1874. *Presented by the French Ministry of Marine.*

"Annales du Génie Civil," for 1874. *Presented by M. Eugène Lacroix, Paris.*

"Rivista Marittima," for 1874. *Presented by the Italian Ministry of Marine.*

"Lloyd's Register of British and Foreign Shipping," 1874-5. *Presented by the Committee of Lloyd's Register.*

"Underwriters' List of Iron Vessels," 1874-5. *Presented by the Underwriters' Registry for Iron Vessels, Liverpool.*

"Intorno Alla Vita ed ai Lavori Scientifici. Di Guglielmo Giovanni Mac Q. Rankine." *Presented by Signor Mariano Quercia.*

"Tableaux de Population, de Culture, de Commerce et de Navigation," for 1870. *Presented by the French Ministry of Marine.*

"Des Lames de haute Mer." *Presented by M. Charles Antoine.*

"Mémoires de la Société Nationale des Sciences Naturelles de Cherbourg," Tomes 9-15 and Tome 18 for 1874. *Presented by the Société Nationale.*

"Occasional Papers." By MICHAEL SCOTT, Esq., 2 vols. *Presented by the Author.*

"Notes on Waves and Rolling, Données Thèoretiques et Expérimentales sur les Vagues et le Roulis." *Presented by M. Bertin.*

"Rapport sur un Mémoire de M. Bertin." *Presented by the same.*

"Extrait des Comptes de l'Académie des Sciences—Institut de France." *Presented by the same.*

"Principes du Vol des Oiseaux." *Presented by the same.*

"Etude sur la Ventilation d'un Transport Ecurie." *Presented by the same.*

"Notes sur la Thèorie et l'Observation de la Houle et du Roulis." *Presented by the same.*

"The Stevens Battery." *Presented by F. H. Thurston.*

"De Roulis par Calme." *Presented by M. Charles Antoine.*

"Nombre d'Oscillations par Calme des Bâtiments de notre Marine." *Presented by the same.*

"Determination du Co-efficient de Résistance Elémentaire K de la Formule $R = K B^2 \sqrt{\ }$ qui sert de mesurer la Résistance des Carènes." *Presented by the same.*

"Tables pour le Calcul des Hélices et des Résistances des Carènes." *Presented by the same.*

"Mémoire sur les Propulseurs Hélicoïdaux." *Presented by the same.*

The following Gentlemen (being duly recommended by the Council) were unanimously elected Members of the Institution:—Mr. Robert Henry Andrews, of the Controller's Department, Admiralty; Mr. James Albert Bedbrook, Engineer, R.N., and Assistant to the Chief Inspector of Machinery, H.M. Dockyard, Chatham; Mr. William John Bone, Manager to Messrs. Cole Brothers, Shipbuilding

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Yard, Willington Quay on Tyne; Mr. Henry E. Brown, Surveyor of Shipping in the Customs and Board of Trade; Mr. William Cooper, Assoc. Inst. C.E., M.I.M.E., Partner of Messrs. Gilbert and Cooper, Neptune Ironworks, Hull; Mr. William Denton, Naval Architect and Ship Surveyor, Sunderland; Mr. William Dobson, Manager to C. Mitchell & Co., Walker, Newcastle-on-Tyne; Mr. John Henderson, junior, Managing Partner of Messrs. David and Wm. Henderson & Co., Shipbuilders and Engineers, Glasgow; Mr. Samuel Holmes, Partner of Holmes, Shaw, Brown & Co., Engineers and Iron Shipbuilders, Bordentown, New Jersey, U.S.; Mr. Samuel H. Pook, Naval Constructor, U.S. Navy Yard, Boston, Mass., U.S.; Mr. John Wigham Richardson, Shipbuilder, Neptune Ship Yard, Newcastle; Mr. John William Shepherd, Manager to R. Napier and Sons, Govan, Glasgow; Mr. James Lewis Sinnette, Surveyor, Lloyd's Register of British and Foreign Shipping; Mr. Bruno Joannes Tideman, Chief Constructor of the Dutch Royal Navy, Royal Dockyard, Amsterdam; Mr. Alexander Hall Wilson, Partner of Messrs. Hall, Russell & Co., Engineers and Shipbuilders, Aberdeen.

The Honorary Secretary next read the List of Officers of the Institution; and it was moved by Mr. Morgan, and seconded by Mr. Barnaby, that the following alterations should be made:—Sir Frederick W. E. Nicolson, Bart., C.B., Vice-Admiral, to be Vice-President; Mr. Charles W. Merrifield, F.R.S.—Associate Member of Council; Mr. A. Sedgwick Woolley—Secretary. The alterations proposed were carried unanimously.

The President (Lord Hampton) then proceeded to deliver the following Opening Address:—

Gentlemen, I now rise to address to you, as is usual, a few opening observations before we proceed to consider the immediate business of the day, and the first point upon which I desire for a moment to touch is to express the feeling which I know will be joined in by every one here—a feeling of very deep and sincere regret for the loss of the Members of this Institution whose names appear at the end of the Report, and to whom, in deference to my own feelings, I must in these observations give the foremost place. This is not the first occasion upon which it has been my painful duty to remark on the vacancies in our lists which have been caused by the hand of death. We have now to lament the loss especially of three very remarkable men. I allude particularly to my own valued friend, and a friend of many of us, the well-known Mr. Laird, the late Member for Birkenhead; and another gentleman whose assistance we have had again and again in our deliberations in this room for many years past—I allude to Mr. Grantham; and last, though certainly not least, must I allude to that distinguished man, Sir William Fairbairn. Mr. Laird was one of our earliest Vice-Presidents. He was a man who had acquired a great and well-merited reputation. He had risen by his own energy and ability, and was justly entitled to those terms which I heard lately applied to him, that he had become one of the greatest shipbuilders in the world. Having known him long intimately in Parliament, and having known his merits both as a shipbuilder and a public man, I cannot pass by the event of his death without recording these feelings of deep regret. I may speak in similar terms of our lamented friend, Mr. Grantham. I need not remind you how justly eminent was the name of Sir William Fairbairn. I may speak of him, I believe, as having been the first and principal introducer of iron as a material for the building of ships. It was by his energy that iron shipbuilding has gradually arrived at that point of perfection at which we now see it, and in his later years I may speak of him without any exaggeration in the same terms which I have just applied to my lamented friend, Mr. Laird, as having become, and as having been recognised as one of the greatest shipbuilders which the world has produced.

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Gentlemen, in turning to the immediate business of the day, I do not think I shall find it necessary to detain you at any considerable length from proceeding to the consideration of the Papers which will be submitted to you; but I cannot refrain from remarking that, although I do not think it will be necessary, in discharging my duty, to detain you at any great length, my feeling is that during the sixteen years in which this Institution has existed, I doubt whether we have ever been brought together at any moment of greater interest and importance in connection with the shipping interests of this country than at the present moment. I allude—and I think you will understand me—particularly to the fact that since our last Meeting in this room, the final Report of the Royal Commission of Unseaworthy Ships has been presented. Last year, and the year before, I found it my duty in the opening observations I made to refer to the appointment of the Commission. Two years ago I referred to it as a Commission then appointed. Last year I had occasion to refer to the preliminary Report which they had presented; and now I have to call your attention for a moment to the fact of their final Report being before us. Whatever differences of opinion there may be—and I have no doubt there are differences of opinion—perhaps in some respects there may be feelings of disappointment—with regard to the contents and substance of the Report, I do not think there will be any difference of opinion or any dissent from my view, when I express my decided opinion that that Report is most important and most valuable. It goes far to meet those complaints which have excited the public mind for the last few years with regard to the manner in which the mercantile marine of this country has been conducted, and with regard to the great question of whether or not it is within the competence of Parliament or the Government of this country to take some additional precautions for the protection of life and property at sea. I need not remind you of the great eminence and ability of the nobleman who was intrusted—and I must say I think very justly and properly intrusted—with the arduous duty of presiding over that Commission. I need not refer to the ability of the Duke of Somerset, nor to the high competence and ability of the gentlemen who assisted him in the arduous duty of that inquiry. I would rather refer—and I shall do that very briefly—to the substance of the Report which they presented. I have already said that I think it not impossible—indeed I think it probable—that in some respects the Report of the Royal Commission may be regarded with feelings of disappointment. Those gentlemen whom I have now the honour of addressing, and especially those who are connected with the Council of this Institution, cannot fail to bear in mind that for several successive years we have been giving our attention—as I think it was our duty to do—to the painful subjects of the loss of life and property at sea, and the best mode in which a greater security to life and property may be given; and no one who is conversant with our previous Meetings can fail to remember the prominence given to the much disputed questions of load line, the survey of ships while building, the question of how far the ships were to be subjected to Government survey before they were to leave their respective ports, and a variety of other subjects. These are questions which have formed the subject of frequent discussions in our proceedings here, and I think it probable that with some portions of the public there may be feelings of disappointment that the Royal Commission have decided not to give any distinct recommendation with regard to these points that have attracted so much public attention.

Gentlemen, there is another point which, I think, has perhaps excited more interest in the public mind than almost any of the other points connected with the conduct of our mercantile marine, namely, the protection of life and property at sea and on this more than any other point the feeling of disappoint-

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ment might arise. The Royal Commission have not thought it right to give any distinct recommendation on the difficult and most important subject of marine insurance. Now, I do not think I shall exaggerate if I say that if there is one thing that has excited the public mind more than another—if there is one point which has inspired the public mind with deep and painful regret more than another—it is the humiliating and discreditable idea that under the mask of prudence, under the plea of protecting and indemnifying themselves from loss by the sinking of their ships, there should be existing in this country men so lost to feelings of honour, propriety, and justice, as to allow their ships to go to sea in an unseaworthy condition in the expectation—and indeed I am afraid there have been cases in which it has been with the certainty—that the insurance would answer their purpose better than keeping their ships honestly afloat, and without regard to the loss of life. I think I do not go too far when I say there have been cases in which unseaworthy ships have gone to sea in hopes that by the sinking of those ships a profit might be derived from their insurance. I should be sorry to think that any such cases had existed to any great extent, but it is well known that such suspicions have been in existence; and I will not presume now to pass any opinion as to whether or not the Royal Commission have exercised a wise discretion in the conclusions at which they have arrived. I cannot refrain, however, from reading to you two short passages from the Report of the Commission, the first of which refers to the circumstances to which I have just alluded. "Competition in insurance encourages carelessness in shipowners, and this increases disasters at sea. The "law has operated in the same direction, not merely by relieving the shipowner from all loss when his "ship has foundered at sea, but by even enabling him in some cases to derive a pecuniary profit from the "shipwreck." These are the plain terms in which the Royal Commissioners have alluded to such cases as those upon which I have just slightly touched. But there is another paragraph of a different character to which I must request your attention. "It appears to us that our whole system of insurance law "requires a complete revision, for not only does it allow the assured in some cases to recover more than "the amount of the loss actually sustained by him, but it also, on the other hand, deprives him of an "indemnity in cases in which he ought to be protected by his insurance." I have not the slightest idea or intention of availing myself of my position in this chair at this moment to throw, or attempt to throw, anything like censure on the decision of the Royal Commissioners. I would abstain from any distinct recommendation on this important subject, especially when I think that what I have just read to you is a most important recommendation. I will not deny that I myself might have felt something like disappointment when I first learned that the Royal Commissioners had determined to abstain from any distinct recommendation on this difficult question; but I have no doubt, looking to the ability and competence of the men that formed that Commission, that they have arrived at a wise conclusion. But the conclusion is this. They say it was not for them to enter into so complicated and difficult a subject; but they record their deliberate conviction that the whole law of insurance in this country requires revision. By that important sentence they have thrown upon the Government of the country the onus and responsibility of dealing with this matter, and I believe I shall only say that to which every one here will respond, when I express my hope that the Government will feel the importance of this recommendation, and the extreme gravity of the whole question, and that it will become at an early day the subject of some measure on their part. But, Gentlemen, although the Royal Commissioners have abstained from making distinct recommendations on those particular points to which I have adverted, there are others upon which they have made important recommendations, one of which bears directly upon that question of the loss of life and property at sea, inasmuch as they

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recommend a system of improved Courts for inquiring into the causes of shipping disasters. That is a practical recommendation of the greatest importance, and I trust that that recommendation will also be borne in mind by Her Majesty's Government. They have also given great attention to another point which bears, as we must all feel, on the maritime interests of this country—I mean the importance of the discipline of our merchant ships, in which everyone will admit there is room for improvement. I think we shall feel that the Royal Commissioners, in making this recommendation, have no doubt made one of very great importance to our maritime interests. There is another recommendation on the part of the Commissioners, the carrying out of which devolves upon Her Majesty's Government, and one which, I say again, I earnestly hope will not be neglected, and that is the recommendation of the Royal Commissioners that the Marine Department of the Board of Trade should be revised and strengthened. Now, Gentlemen, this touches very closely on the subjects to which I have adverted; and I must say I think that the Royal Commissioners have done well, and have entitled themselves to public gratitude in recommending the strengthening of that department of the Government upon which so much depends in their dealing accurately and well with those important subjects. A great deal depends, as we all know, upon the manner in which that department of the Government fulfils its functions, and I hope the Government will not lose sight of this very important recommendation.

Now, Gentlemen, the views of the Royal Commissioners have been embodied for the most part in a Bill—a copy of which I hold in my hand—which has been introduced into the House of Commons by the Government. Upon the back of that Bill I find the name of Sir Charles Adderley, as the head of the Board of Trade, and the names of two other members of the Government. After what I have said with regard to the contents of the Report of the Royal Commissioners, of course there will be no feeling of surprise that the Bill introduced by Her Majesty's Government—and introduced, I think, we must all acknowledge, with great promptitude, and without any unnecessary loss of time, with a view of carrying out the recommendations of the Commissioners—is of course closely in accordance with the nature of those recommendations. As the Commissioners abstained from any distinct recommendations with regard to load line and surveys, of course the Government Bill abstained from any legislation or any attempt to legislate upon those difficult points. Whether or not they are doing wisely in so shrinking from those questions it will be for Parliament to determine.

But, Gentlemen, simultaneously with the introduction of the Government measure, I find another Bill is introduced into the House of Commons of an opposite character, and that Bill bears upon the back of it the name of Mr. Plimsoll, the Member for Derby, together with the names of four other Members. Although Mr. Plimsoll is the real introducer of the Bill, Mr. Roebuck's name is upon it, and also Mr. Kirkman Hodgson's, and last, but not least, the name of my honourable friend whom I see sitting in this room, Mr. Samuda, the respected Treasurer of this Institution. Here we have two schools—if I may so express it—in direct competition the one with the other. The Government introduce a Bill in which they practically say, "We think the adoption of a load line and any regulations with regard to the stowage "of cargo, or surveying ships during building, or before leaving port, are matters that are better left to "the discretion of the shipbuilder and shipowner." On the other hand, Mr. Plimsoll and Mr. Samuda come forward and say the time is come when we ought to legislate upon these points, and to lay down strict and stringent rules for the protection of the public. Well, Gentlemen, when such doctors differ it will certainly not be for me—I doubt whether it will be for us at all—to step in and say what will be the

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arrangement between them. But this must be settled by the wisdom of Parliament, and the public will have this great satisfaction, that public attention throughout a series of years has been called to an extent never before known to the magnitude and importance of this subject. It will now be for the Government and the Parliament of this country, with the advice and all the assistance they are able to command, to say which are the soundest principles. Let them lay down—as they have laid it down by appointing this Commission, and by introducing these Bills into Parliament—the one great principle which the public demands, and which the Government and the Parliament of this country are evidently willing to concede—that our navigation shall no longer be exposed to those frightful dangers which have hitherto attended it. That seems to be the principle upon which we may rest contented. I think that the public may rest contented from the fact that these Bills are before us. Then you must bear in mind that in the year 1873 that remarkable and valuable Act was passed, by which the Board of Trade have been empowered and authorised to exercise their great powers for the protection of the public—powers which I hope will continue to be exercised with as much vigour and energy as they have been hitherto, and, which I think I may without fear of contradiction say have tended much to promote the public safety.

Gentlemen, the Papers which are coming before us to-day are not so numerous as we expected. Two out of four have been withdrawn in the course of this morning; but those that remain are extremely important. They bear distinctly upon those questions upon which I have ventured to touch, and I am not sorry that, by the withdrawal of other Papers, we shall be enabled in some degree to relax that strictness with which, as Chairman, I have always felt it my duty to adhere to the rules with regard to time. I trust we shall have the great advantage of hearing those great questions which are the subject of these Bills, and to which the attention of the Royal Commission and the public has been directed, fully discussed in the course of this morning.

Gentlemen, before I conclude there is only one more point on which I have to touch, and I do so with very sincere regret. It is the fact that our valued friend, Mr. Merrifield, the Honorary Secretary of this Institution, has found it necessary to communicate to the Council this morning a notice to the effect that his official duties in the department of the Government with which he is connected create such a demand upon his time, that he finds himself obliged to request that he may be relieved from those duties devolving upon him as our Honorary Secretary. This communication was conveyed in such terms to the Council as rendered it necessary for them to accept the resignation; and the only consolation we had was, first of all to pass unanimously a vote of sincere thanks to Mr. Merrifield for the valuable services he has so long tendered to us, and to express our great regret at losing him; and further, we have the satisfaction of receiving from him an assurance that so far as his leisure will permit, he will always be willing to promote the objects we have in view. I think I am bound to add that, with regard to the future, the Council feel a confidence which they could not have felt some time ago, that in the person of Mr. Woolley the loss we have sustained by the retirement of Mr. Merrifield will, ere long, be amply compensated. With these observations I will now call upon the authors to read their Papers.

[The Report was then adopted].

Since the issue of Vol. XV., the following Gentlemen have been added to the lists of Members and Associates respectively:—Messrs. Robert Henry Andrews, James Albert Bedbrook, William John Bone, Henry Edward Brown, William Cooper, William Denton, William Dobson, John Henderson, junior,

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Samuel Holmes, Samuel H. Pook, John Wigham Richardson, John William Shepherd, James Lewis Sinnette, Bruno Joannes Tideman, Alexander Hall Wilson—Members; and Messrs. Mohammed Anis, Mohammed Arif, Gainsford Bruce, Barrister-at-Law; Pierre Delaitre, Ingenieur de la Marine, West of France Railway Co.; Herman Gruson, Iron Founder and Engineer, Bückau-Magdeburg; Amable Lagane, Ingenieur en Chef des Forges et Chantiers de la Mediterannée, La Seyne, France; Thomas Milward, Manufacturing Marine Engineer, Swansea, South Wales; George Mathias Sinnette, Milford Haven Shipbuilding and Engineering Works; William Lloyd Wise, Consulting Engineer and Patent Agent; James Kirwood—Associates.

During the same period the Institution has sustained the loss of the following Members and Associates by death:—John Laird, Esq., M.P., Vice-President; Thomas Lloyd, Esq., C.B., Vice-President; Rear Admiral F. A. Campbell, H. D. P. Cunningham, Esq., R.N.; William Dudgeon, Esq., and Andrew Fountaine, Esq., Associates.

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PAPERS AND DISCUSSIONS.

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ON IMPERIAL LEGISLATION AS IT AFFECTS NAVAL CONSTRUCTION AND THE ENGLISH MERCHANT NAVY.*

By John Scott Russell, Esq., F.R.S., Vice-President.

[Read at the Sixteenth Session of the Institution of Naval Architects, 18th March, 1875; the Right Hon. Lord Hampton, G.C.B., D.C.L., President, in the Chair.]

The Queen's Speech at the opening of Parliament has ordered legislation on the Mercantile Marine of England. The Board of Trade, in obedience to that command, has prepared a Bill proposing better laws for ships, shipowners, ship's husbands, shippers, shipmasters, shipbuilders, and seamen.

As this Society contains many eminent shipowners, shipbuilders, ship insurers, shipmasters, and distinguished legislators, naval officers, and merchant seamen, it is one of their first urgent and most fitting duties to discuss and to take action in a question which may most seriously affect all questions of naval construction in the merchant fleet of England for the future.

The object of this Paper is to enumerate and suggest the possible objects of legislation, and to raise a discussion on each; and I beg to call serious attention to the Bill itself, which has been introduced into the Commons by Sir Charles Adderley, and to point out that we are not to form any conclusions as to *that* Bill becoming law; but must bear seriously in mind that the motions of Members of the Legislature may entirely *transform* that measure before it becomes law. I believe it has been already transformed.

The objects of legislation have been and may be such as to affect and regulate directly or indirectly the dimensions, proportions, form and structure, and therefore the seaworthiness of all our merchant fleet.

1.—*Length and Breadth.*—Shipping laws, fifty years ago, gave strong inducements to building and owning bad ships, well worthy the name of coffins. This they did by

* Received 13th March, 1875.

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practically placing a heavy penalty on a ship with adequate beam for standing up, and giving a money premium for ships that were crank and liable to upset. With many old friends of mine I long worked hard to get this law abolished. After long, painful struggles we got rid of it. But such is the effect of old custom and evil tradition, that we still suffer from it, and what we still call builders' tonnage is a relic of that old superstition, and where crank ships are still built it is that tradition which builds them.

The traditional limitation of the beam and stability of a ship having been got rid of by our modern or Moorsom's law of tonnage, a new proposal has now been made by eminent men to place a legal limit on the length of ships—saying that the length of a ship shall be within some fixed proportion of its breadth. I beg to call the serious attention of this Meeting to that point; it is not proposed in the Bill, but it is planned by legislators.

The question I put to this Meeting is, Do you think some fixed proportion of length to breadth decides the seaworthiness or unseaworthiness of a ship? May not a well-formed longer ship be better than a shorter; I mean a better sea boat?

I begin by frankly admitting that an ill-proportioned misshapen ship would have her weakness much increased, her unseaworthiness exaggerated, and her unmanageableness in a sea-way aggravated by mere drawing out of her length. That, however, is not the question for practical discussion. The vital question is this—may not the practical case arise of a vessel destined for given service, being rendered better suited for the wants of that service if of a given length and breadth; may not that case be met by giving a long ship certain forms, proportions, provisions, and qualities, and so making her as good a ship at sea as a shorter but less serviceable ship? The answer, I trust, is, that all capable shipbuilders know how to modify the shape, structure, and disposition of parts in a ship, so as to render the long ship as entirely seaworthy as an ordinary shorter ship. Of course it implies that the shorter ship shall considerably differ in several ways from the longer one. The question how, is for us shipbuilders? I need not here now argue the question. I leave it to you.

2.—I next call your attention to *Builders' Tonnage Law.* It is a relic of the past. It is all wrong. It means nothing. It means much. It is virtually a penalty on giving a ship sufficient beam at the load line. It tends to make a heavy-rolling, overladen, top-heavy, upsetting, bad ship. It has but one good point—if that be one. It helps a sharp builder to cheat an ignorant shipowner. It helps a sharp shipowner to get the better of a screwing builder. Where both are sharp, each tries to use the clause to get an advantage, and the result is often a bad ship.

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The reason of the badness of the builders' tonnage law is this:—That a sharp builder will build you a cheaper (to him), and less profitable (to you) ship at a given price, than you desire to have and expect to have, and yet it will be true to builders' tonnage. It will have less buoyancy, less carrying power, less stability, less cargo than intended, yet it will be paid for on the scale of a better ship.

The builders' tonnage law, therefore, as a test of price is an error, and in policy a blunder. The real elements of cost in the construction of a ship are not mainly dependant on absolute beam; now the law of builders' tonnage makes beam nearly everything.

The ruling element of capacity or cargo-carrying power in a ship's dimensions is: (1.) The entire girth of the ship amidships. (2.) Her length. (3.) Shape.

If you ask me, what law of tonnage for price, or builders' measurement, will come nearest the truth, do justice to builder and buyer, and make the best ship makeable for given cost? I give the following:—

Take the ordinary law of tonnage. You will find that the limit which is put to breadth encourages the narrowest possible breadth, great depth, square bilges, and wall sides. Allow me merely to say that the cost of this ship to me, the builder, supposing it to have an iron deck, as all our long iron ships have now, is exactly the same as the cost of this other ship which I am going to give you. I will take a ship of larger dimensions, I will give her beautiful round bilges, I will give her the same height out of the water; I will give her the same deck—she has a much larger beam, and every quality of that ship is better than the quality of this. This ship costs me to build exactly the same sum, and, perhaps, even less, which depends on my skill, and the cleverness of my men; it gives me in every respect a better ship, it gives me a ship that carries much more, but that has all the good seagoing qualities of which this has the bad. Now, allow me simply to say that I have known fleet after fleet of merchant steamers ruined by this tonnage law, which made it to the interest of the shipbuilder to build *this* ship, and made the owner think it was to his interest to get *this* ship, instead of to get *that* one. The reason is simply this, that with a given girth—if I might talk technically—I would say that the cost of a ship to the builder of a given structure is proportionate to the girth of her chief material, and as the girth of this vessel, with more beam and in every respect better, is the same as the girth of *this*, we would rather build *that* ship, if it was not for this intolerable builders' tonnage, which I should entreat the law of the land to change, for this reason:—That if the law changes it, it will be valid in contracts, but at present all contracts about shipbuilding are valid on the present tonnage; and I do not know that we could possibly by any volition or resolution of ours change it. It is, therefore, worthy of most serious attention. Let the builders' tonnage for the future be arrived at

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by taking as length the present builders' length; take as beam, two-sevenths of the midship girth; as depth, one-seventh; and then the common formula will give builders' tonnage quite true and fair. It will encourage more beam, better shape, and better qualities.

The details of this I need not give. All I have to say is, that I can give you a much better, more seaworthy, durable, and profitable ship one way than the other. I also say that a good ship would in that case be as profitable to the builders as the bad, and the shipowner would not be driven by greed to order a bad ship. In short, the price paid would bear just proportion to cost. With this law, wall-sided, square bilged, flat-floored ships, crank and heavy rollers, would disappear.

It must be understood that I am speaking now of large and costly ships of best modern construction of iron, with iron deck and all the modern improvements; for common small ships the law does little harm, and would not be worth the trouble of change.

The conclusion you will draw from all this is probably that for the building of ships we do not see that Imperial legislation is likely to be useful. But the legislation of Lloyd's is practically most useful, and should not be changed by legislation.

3.—*The Tonnage Law of Modern Legislation* is, as you know, the law which affects the merchant employment of ships, the cost of freights, and the shipping taxes and tonnage dues—in other words, mercantile tonnage. This, we are glad to know, is now so exact and so just that no one need complain, and it is being adopted by all nations, even by the indomitable but recusant Suez Canal.

4.—The next *Rules* or Laws of *Merchant Shipping* at which we arrive are a curious example of the self-made legislation for which our ancestors were famous. What we call *Lloyd's Rules*, or Lloyd's Committee of Legislation, is what we may call *old custom* or *self-made* law. We all obey it; we all think it for our good; we find fault with it as Englishmen do with everything, and we cling to it and obey it; we feel that it is law because it is just; we feel free to reject it if we like.

It has been proposed by some legislators that, instead of being guided by Lloyd's Rules in the details of ship construction and ship's condition, the whole laws of ship construction and condition should be handed over to the Board of Trade, or some other branch of Government. Such a proposition is so grave as to demand serious attention.

No man knows the faults of Lloyd's Registration better than I do; none has more strongly objected to them where they seem to err. But also no one appreciates their good deeds, their good character, and their high qualifications more than I do. I should

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therefore do all in my power to give more and more influence and authority to Lloyd's Committee for the classification and registration of ships according to their merits, and for the examination and record of their condition and seaworthiness.

All I now say, then, is, that I think their laws admirable, but they should be constantly revised; that they should provide for and favour every improvement, even in advance of their own laws; that, if legislation could add to their power and extend their influence or increase their executive strength, it should do so. But I should not interfere with them by legislation, unless they themselves wanted it and asked it.

5.—*Legislation* and the *action* of the *Government* may be usefully employed in one way:—For the *public interest* and the public security, the Executive should obtain and register, for public use, *all knowledge* of the *actual condition* of the merchant fleet, and all facts concerning its seaworthiness and safety of life.

But a marked line must be drawn between Government *registration* of *facts* and Government *interference* in *business*. The one should be encouraged, the other interdicted. It may arrest crime, it may punish crime; but the people must be left quite free to do their own work their own way, on their own untrammelled responsibility. No Government should have power to say to a man, "Stand by! I know your business "better than you; let me do it!"

The full responsibility, then, of the shipbuilder must rest on himself alone; the full responsibility of the ship must lie with her husband or owner; the full responsibility of the navigation must rest with the captain. The possession and registration of knowledge for the public good is, however, a manifest and inevitable duty of Government. Government should obtain and register the dimensions, tonnage, and character of all British ships; should carefully watch and record their condition, and furnish all useful information thereon. It should abstain from all active interference except the prevention of harm or crime.

6.—What, then, are the *facts concerning a ship*, the knowledge and registration of which will promote the public good, if done by Government?—

I.—A complete record of shipping of the British Mercantile Navy, comprising:

(1.) Builders' certificates.
(2.) Owners' registry.
(3.) Plans of ship.
(4.) Structure of ship.
(5.) Records of ship's work, or log book.
(6.) Records of ship's seaworthy condition on each voyage, sailing and arriving.
(7.) Lloyd's Reports.

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II.—A complete certificate and record of seamen, officers, and captains, certifying their apprenticeship, education and training, the ships they have sailed in, the voyages they have made; in all cases registering facts, not giving opinions. The certificate of each man to have as part of it this record in full or in summary.

III.—In cases of harm or crime or danger to public well-being, no department of the Executive Government shall have power to do more than to enquire and give information to a legal prosecutor, who shall be empowered to enforce the common laws of the land on the wrong-doer.

7.—In addition to the records of seamen, officers, and captains, Government may and should provide *Institutions* for the *rearing*, *education*, and *training* of the seafaring community; so as both to aid and extend the navigation, commerce, and trade of the country, and prepare an organization competent to the defence of the British Empire. This implies training ships, naval schools, sailor apprenticeships, and colleges for naval science and practical navigation.

8.—All these matters require so much technical knowledge and practical experience that a *special Government organization* is required exclusively for these purposes. Whether the whole questions of (the affairs of) the Merchant Fleet should remain in the hands of the Custom House, or of the Board of Trade, or should be transferred to a special department of mercantile marine is a question frequently put. That is more for the Government itself to settle than for us outsiders even to suggest. What I do venture to suggest is, that the whole legislative and executive action concerning so important a national interest as the merchant fleet of England, should be placed exclusively in the hands of the most able, competent, and experienced men of England, selected for their special ability to deal with each branch of an important but difficult subject. I think it is the general opinion of the best men in every department of this subject, that these matters are not now placed in the hands of those most competent to deal wisely with them. Fitter men are even more needful than better legislation.

9.—*International Laws* of merchant ships must be made and executed by the intervention of Government. Unity of lights, unity of rules of the road at sea; harbour, canal, and channel regulations—all should be and must be arranged between Governments—by International Commissioners, Ambassadors, and Consuls. Where danger and destruction arise from international misunderstandings, the Government departments are entirely responsible; several such misunderstandings at present exist.

10.—*Compulsory External Marking of Ships* with what is called a *load line*, has been often proposed and much discussed here, so that I need say little on that point. That

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the proportion of the bulk of a ship, in the water and out of it, has much to do with her seaworthiness is certain. It is equally certain that that will vary in different proportions and conditions of ship. It is equally sure that what is safe for one voyage may be unsafe for another. The captain and the owner's experience can alone judge this point for each special case.

I have long desired and recommended the visible marking of a load line on all ships. I still commend and wish to enforce the clear marking and showing of light and load draft, and displacement, on a drawing of the ship carried in the ship's papers. I should like to see the side of every ship painted light up to this load line and dark above. But I do not think as some do, as perhaps I may have done, that this line should be made compulsory, so that an owner or captain knowing his own ship to be safe for a given voyage on a deeper line, should be prohibited on his own responsibility from using it. I recommend, therefore, that the recording and visible marking of a load line be compulsory, but that the practical use of it be left discretionary.

The line to be marked should be that which, according to the ship's tonnage, leaves, say, one-fifth of the capacity of the ship above the line, with, possibly, this provision, that water-tight compartments above the main deck shall count for half their bulk.

Summary.

As regards ships and shipbuilders, my opinions are as follows:—

The law and custom of shipbuilders' tonnage should be altered, so as to substitute girth for beam.

All British ships should have their strength, structure, capacity and qualities certified, registered, and placed on the ship's papers.

As regards ships and shipowners, there should be registers and records kept of the condition, lading, ballasting, freeboard, draught and trim of every ship, on each voyage on sailing and arriving; but the full responsibility of these should rest only on the responsible owner.

As regards shipowners and British subjects, there should be one registered owner, to act as responsible ship's husband; there should be an official, of high standing, as public prosecutor for the case of loss of life. The common law of the land is sufficient for public protection against shipowners, as against any other carrier of goods and passengers.

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As regards British commerce and public interests, the education, training, discipline, and well-being of the seafaring class has become a question of pressing national interest, both as regards seamen and officers—both with reference to merchandise and war; records and registers of able seamen and competent officers and captains are now of equal importance with registration and records of ships.

DISCUSSION.

Mr. J. D'Aguilar Samuda, M.P.: My Lord and Gentlemen, I should not have risen at this early portion of the debate, except that I consider it will be probably for the convenience of the Meeting that I should explain more perfectly than appears to me to be understood generally, some of the views, and some of the important views, that are attributed to me with reference to this subject; and I would take the opportunity, at the same time, of pointing out what are the general and broad principles upon which I form my ideas of what is required for Government Legislation with regard to this matter. First, I will refer, without in the smallest degree complaining of that which has been stated of me by the noble Chairman, to the circumstances under which my name appears upon the Bill of Mr. Plimsoll. It has been noticed by our noble Chairman that there are two Bills before the House at the present moment, and that a marked distinction and difference exists in the principle of those two Bills; and as the Chairman has properly noticed that my name appears upon the back of one of them, which is perfectly accurate, he naturally draws the conclusion that I am therefore prepared to endorse the principles, generally and absolutely, of that Bill. Now, I am not. And perhaps I might, before proceeding further, say that I feel the circumstances in which I am necessarily appearing before the public, and before the House of Commons on this occasion, do require some explanation, which I am ready to give here, and shall be equally ready to give at the right moment in the House. My connection with Mr. Plimsoll's Bill arose, two years ago, from the great sympathy which I felt with the objects which he had in view and desired to accomplish. I felt that it was imperatively necessary from the facts which were continually being presented before us, and the scandals that existed in many instances arising from unseaworthiness and other circumstances which were producing such great loss of life at sea, that every one who stood in relation to shipbuilding in a position similar to that in which, by a long course of connection with it, I more or less did stand, ought to be ready to assist in making all such changes as could with advantage to the public be made by legislation. But I felt at the same time, and I pointed that out to Mr. Plimsoll, when I put my name on the back of his Bill, that I did not know the entire details that he meant to bring forward, and that some of those details which he had already shadowed forth I could not approve of. And upon the discussion which took place upon the second reading of his Bill in the last year's Session, for which I voted, I pointed out to the House generally that which I am now pointing out to this Meeting, that in voting for a Bill to have the restraining influence which I wished it to have upon the misdoings of those whose acts required that they should be restrained, I neither approved of those two broad principles which were laid down in his Bill, that a load line should be definitely specified upon the authority of the Government, because that, in my opinion, should only be upon the responsibility of the owners; and neither did I approve of compelling every ship to submit itself to

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the approval of Lloyd's Register or any other similar Institution, if the public thought fit to accept it on the responsibility of the builder and the owner without such registry. Therefore I want, in the first instance, to point out that as far as those two particular points of Mr. Plimsoll's Bill go, instead of being a supporter of that Bill, I am myself a direct opponent of it. Now I feel very strongly that interference on the part of the Government is by no means an unmixed good. I feel that it is one of those conditions which ought to be accepted with great caution, because I feel that there is great truth in many of the propositions which have already been laid before us by our worthy Vice-President, and especially as to the probability of mischief, which might arise from inducing a certain mode of construction, which would be certain to follow fixed rules, in the designs of vessels. I do not think that can be left too broadly in the hands of the builders; but that something should be done to prevent the scandal that exists at the present moment from the loss of ships, which ships ought never to have been lost at all, I am myself strongly of opinion. Then when I considered what was at the base and root of the whole of this subject—and I have already on several occasions in Parliament expressed myself very strongly about it, and now I find I am supported in that view by my honorable friend, the Member for Hastings, Mr. Brassey, who has brought the matter of insurance in an important motion before the House—I came to the conclusion long since that the law of insurance, which is a thing that is legitimately within the power of Government and the province of Government to deal with, is one of those which, when properly corrected, will advantageously influence the position of the mercantile marine. I asked myself this question, Why should there exist in cases of marine insurance a totally different principle from that which exists with regard to the insurance of houses and of trading stock generally. The object of insurance has always been understood to be, at the most, indemnity from loss. The object of insurance would be wholly misplaced, in my opinion, if it could be made use of as an incentive to gain. Yet the rules upon which marine insurance, contrary to land insurance, is carried out, do enable most important advantages to be gained by those who seek to make use of their policies with the view of obtaining them, if accident should bring it to their chance to make use of their policies. Now I want to make it understood most clearly that I am not descending to that extremely few, if any, in the class of shipowners who could be charged with intentionally, and with advisedly, clothing themselves with the power of insurance for the sake, and with the intention, of losing their ships; but I must maintain that if the law is such that a man can be relieved of that anxiety, which all of us feel presses on us so much in carrying out our general occupations, be it of industry, be it of commerce, or any of the matters connected with our ordinary life operations, the amount of skill and consideration of every single circumstance which will add to the seaworthiness of his ships, and consequently to the probable success of his journey, must be in some degree blunted if he can, after the loss has occurred, instead of finding himself at least something worse, find himself considerably better off than he would have been had he the best customer he could find for his ship. I would for those reasons change the law of insurance too, with the view, first, of absolutely restraining the power of insurances being made for any amount beyond that which the value of the ship itself represents. The great point which we have to look to in this matter is the advantage of the public generally, because it must be plain to everybody that every loss at sea is a loss of so much public money, and every one has to pay for every single ton of goods which is transported throughout the world afterwards, an additional proportionate sum to represent that loss. Therefore my own view would be that we should go still further, and in addition to that over-scrupulous attention to improving in every way the seaworthiness of the ship, both by the selection of the captain (a most important matter), by the selection of the crew, by the supply of spare

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spars and spare sails to an extra amount, by everything that could add to the efficiency and the equipment and seaworthiness of the vessel, compel every owner, when he made his insurance, to make it upon the condition that he should only receive back a per-centage, say 75 per cent, on the entire loss for which he had insured. It would be no penalty upon him with regard to the amount of the insurance, because his premiums would be in proportion to the amount that had to be returned to him; but he would by that means become interested in the safety of the arrival of his ship in port to the extent of a fourth of her value. Therefore, I believe we should by that means, by that care in the selection of the builder to begin with—beginning right at the bottom of the tree—by that care in obtaining character instead of price in the building of the ship, by that care subsequently which he himself would bring to bear in the equipment of the ship, and in the fitting it out for the voyage it had to go, get rid of many points of difficulty which exist at this present moment. And if I wanted to be strengthened in that conclusion, I would refer to the fact that the highest class of shipowners we have throughout the United Kingdom, are themselves their own insurers to the full extent, or nearly so. Therefore we have this fact brought prominently before us, that whilst those who lose the least ships are those who sail them entirely and absolutely at their own risk, it cannot be very bad to induce the remaining portion of the community to accept, in a smaller degree, the same character and the same risk, which these model houses are continually presenting to them, compelling them, if they go into the owning of ships at all, to feel that they do so with a responsibility of a fourth of the capital on their own shoulders. I am afraid I have gone at too great a length into that matter, because there are a few other matters connected with the legislation that is now before us which I should wish to offer a few remarks upon, and which I will trust to the kindness of the Chairman to allow me to put as shortly as I can. Having dealt with that which is the main subject, and at the root of the whole thing—without which I believe no legislation could be justifiable or advantageous—I will now pass over in review rather quickly the matters which I think ought to be dealt with. Now, first, as to the load line, I have pointed out that I object altogether to the existence of any Government load line, but I fully agree with the remarks in the Paper that the load line should be recorded, and I would go to this extent, that the responsibility of the load line should lie entirely with the owner of the vessel, and that he should be compelled, when he entered out his ship, to enter out the load line to which he intended to depress her, and the public would by that means have an opportunity afforded to them of knowing the quality of the ship, and the risks they ran by either loading in a ship which they thought was loaded too deeply, or loading in one which they conceived to be a first-class risk, by means of the extra amount of freeboard which was proposed to be given. I would therefore confine the action of the Legislature to the necessity of recording this load line with a sufficient amount of accuracy, and that if the vessel had the load line exceeded which their record would show, when it went to sea, that the owner should bear all the responsibilities of having departed from the contract which he made with his shippers to give them a certain amount of freeboard, which afterwards he did not keep, or having kept that load line, should be free from the imputation of having laden his vessels below that which he intended. Then I quite agree that deck cargoes, which are very great and frequent sources of mischief, are suitable subjects for legislation to some, and to a considerable, extent. I think, first, that deck cargoes should not be allowed to be carried except in the same way that has been notified by the owner it was his intention to carry them, and to the extent he intended to carry them, when he entered out his ship. Always provided, when the ship is starting to sea no objection is taken as to the unseaworthiness of the ship, she might be allowed to have these deck cargoes, but I would put this restriction upon them by law, that when those deck cargoes were entered out to be

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carried, they should have to pay tonnage dues for having carried that amount of deck cargo, in addition to that which the ship was registered for below the deck. Then I certainly think that improved courts for the examination of all these matters are most important. I think it a great subject, and that it is well worth the consideration of Parliament and this Meeting, whether a better result might not probably be arrived at in the decision of these matters, if nautical assessors, with a sufficient amount of knowledge, could be made use of, instead of, or perhaps in conjunction with, juries. I believe, generally speaking, there is so little knowledge on the part of juries, that they are so capable of being misled by clever and adroit counsel in the consideration of cases, that you do not get to the bottom of these matters with that amount of certainty (and certainty is the essence of everything) which is desirable in justice and in law, and I think that the advantage of having nautical assessors should be more largely developed in the legislation which we are carrying out at the present moment. With regard to the improved discipline of sailors, no doubt that is a thing materially wanted. There is no doubt that, wholly apart from the faults and errors of the shipbuilder, and even of the shipowner, a great many ships are rendered unseaworthy by unseaworthy crews, and I am of opinion that anything which would tend to improve the discipline of the crews, is rightly a subject for legislation. That is a matter which forms part of the intention of the Bill before Parliament. There are some matters in it which are liable to observation, and which perhaps require correction; but I think, as a general rule, it is a wise measure, and one in the right direction. The Board of Trade improvements are also, I think, equally necessary to be performed; but I feel that I have trespassed too long already upon the time of the Meeting, and I would trust to the noble Lord in the chair, and the Meeting, to give me the opportunity of explaining afterwards anything which I have said, by reason of my not having been able to complete wholly the remarks which I wished to make.

Mr. Charles H. Wigram: I think that, probably, our shipping suffers more by attempts at legislation owing to many of those who attempt to legislate not having really a knowledge of what are the difficulties they have to encounter, and how contracted the space is in which you can legislate. I do not mean to refer to the working of the whole proposed Bill, although the more I looked into many parts of it, the more I found how little understood many of the difficulties were. I must say, it really appears to me that people who have not availed themselves of the returns presented from the Board of Trade,* do not know to what extent the loss of ships and the loss of life on board ships really exists. I take those ships which have come under the "Passenger Act" for carrying passengers, and with regard to which returns have been made to the Board of Trade, dating from 1847 to 1872 inclusive. That is a long period you will say; but during that period the total number of passenger ships—I use the term passenger ships as understood in the return—is 22,186, and the total number of adults conveyed in that time is 6,235,713. Therefore we are dealing, you see, with enormous numbers; and during that time the per-centage of those ships lost is ·46, and the per-centage of lives lost is ·09. Now, certainly, I was not prepared to see such a small per-centage of loss of life and of loss of ships; and I daresay other gentlemen will be in the same position.

The President: Is that the Board of Trade return?

Mr. Wigram: Yes.

* I should have spoken of the return as coming from the Emigration and Colonial Land Commissioners, *Colonization Circular*, 1874, *Appendix No.* 9. Not a Board of Trade return.—C. Hampden Wigram.

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Mr. J. Scott Russell: Would you kindly give me the figures again?

Mr. Wigram: The total number of ships was 22,186; the number of adults conveyed, 6,235,713; the per-centage of ships lost, ·46; and the per-centage of lives lost, ·09.

Mr. J. D'Aguilar Samuda: That is, one in 200 lost?

Mr. Wigram: Yes.

The President: How do you reckon the voyages of those ships?

Mr. Wigram: That is a return of all ships coming under the "Passenger Acts."

The President: Do I understand that each ship appears only once?

Mr. Wigram: Each ship may appear more than once.

Mr. J. Scott Russell: I think some of us here do not quite understand the figure of per-centage as to the number of ships—the 22,000 ships. What is the fraction of the ships?

Mr. Wigram: ·46.

Mr. J. Scott Russell: There is a mistake in that fraction.

Mr. J. D'Aguilar Samuda: Is it the number of ships, not voyages?

Mr. Wigram: I think it is the number of voyages. Each voyage is a ship in the Board of Trade return. Still, as regards the loss of life, it holds good. I think it shows that the loss of life is very much smaller than has been considered is the case.

The President: If we are to take each ship as only appearing once, then 22,000 in twenty-five years does not seem much.

Mr. Thomas Brassey, M.P.: Is the Channel packet service included in the total number of passengers conveyed?

Mr. Wigram: They do not come under the Board of Trade surveyors.

Mr. J. D'Aguilar Samuda: Yes, I think they do.

Mr. Wigram: As to one clause specially referred to in the "Merchant Shipping Bill"—I mean the clause as to the number of boats which a ship is to carry—the Act, as at present drawn, proposes that each ship shall carry boats for the whole number of her adults on board. Of course, in a sailing ship, not carrying passengers, that is easily complied with; and, at the present time, I believe most ships carry more boats—amply sufficient. A ship of 1,000 tons would not have more than thirty-five souls on board, and the safety of those is easily provided for by the boats she does carry. But when you come to large passenger steamers, it becomes an impossibility. I have had furnished to me—from the builders, and the representatives of many of the large passenger companies, and I have got from other sources—the particulars of the passengers carried, the size of the ships, and the number of the boats. Now, take the large steamers running from Liverpool to New York, vessels of 5,000 tons gross register tonnage. For instance, I find that the *Britannic* at the present time, under the "Passenger Act," has ten boats. Now the builders of that ship, and I think it is a very fair example, bestowed great pains as to how they could place the greatest number of boats so as to be actually efficient. They say, in a letter to me, that a boat, to be efficient, must be put in a place where it can permanently remain, so as not to be disturbed by the

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working of the ship at sea or in harbour, where she can be put firmly in her chocks, and firmly cleated down, &c. The *Britannic*, the vessel I refer to, is supposed to carry 1,270 souls. She has only, at the present time, ten boats. Upon looking at her drawing, I see I could, possibly, put in two more boats of 28 feet long, although that would have to be in a place where it would be inconvenient, and where they would be liable to be washed away. I think you may take it, that, in those large steamers, it is quite impossible to put in, effectively, more boats than they at present carry. I do not mean if you put a boat down in the middle of the deck, but to put them where they will be efficient, where they will not interfere with the comfort and convenience of the passengers, and where they would be readily available in case of accident. I could go through a list of more vessels, but they all come to the same result, and I will not occupy your time in doing it. But, in this inquiry which I have referred to, in looking over these particulars as to the dimensions and quantity of boat space carried by one class of ships—which I think every one will admit have always been thoroughly efficient in every respect—really, even there I find that those vessels do not comply with the requirements to the extent suggested in the proposed Act of Parliament; and the vessels I refer to—which I think you will say I am justified in doing—are the ships of Her Majesty's Navy. Neither in quantity nor in space are the boats they carry sufficient, or what would be required of a merchant ship to carry. Now, of the largest ships of all, the iron-clads, I will take the *Bellerophon*, because I have calculated the size of her boats. Her complement of men is 545. The number of men that each ship is supposed to carry, according to the Government scale, is 600; but, taking the cubic contents of those great boats at 17 feet, the space required by the "Merchant Shipping "Amendment Act," she would only be able to carry 541; but out of that she has one 42-feet steam pinnace which should carry 140; and if I deduct the size of the steam launch, and the number of men the Government allow, she should carry, from the total numbers, I find that that ship has only boat space for 426 men, instead of 475, which she ought to carry. Now, really, I think, if with regard to the ships of Her Majesty's Navy, it is sufficient to give a boat space of 10 feet, that the merchant ship should be allowed the same space, and not 17 feet instead. Those are all points which I believe will come into consideration when the Bill comes into Committee. I hope that I have not occupied your time unnecessarily in putting these facts before you.

Mr. Thomas Brassey, M.P.: I did not come here with the intention of making any observations at a meeting of this kind, which is composed of persons of great technical knowledge, and where those who do not possess that technical knowledge have very much to learn; but I conceived that, as a Member of the House of Commons, it was my duty to come to gain information from those who do possess this important technical knowledge, which information I will endeavour to make use of in my legislative capacity. My Lord, I have to thank you for the kind terms in which you thought fit to speak of the labours of the Royal Commission on unseaworthy ships. I am confident that the Commission endeavoured to do their duty with impartiality, and to go to the very bottom of the important and most difficult problem referred to it. I am glad to find that the two eminent shipbuilders who have addressed this Meeting have, in many important respects, supported the views at which the Commissioners arrived. I may say for myself that at the close of our investigation I, in my own mind, was deeply impressed with the conviction that what we wanted, in order to establish greater security at sea, was not so much legislation as an improved and more effective, and thorough, and perfect administration of the laws which actually exist. The Act of 1873, as your Lordship pointed out, invested the Board of Trade with

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powers to do those very things which Mr. Plimsoll has so strongly and forcibly recommended. What Mr. Plimsoll says is, that an overladen and an unseaworthy ship shall not be allowed to go to sea, and the Board of Trade, accepting that view, obtained powers under the Act of 1873 for preventing all ships which were overladen and unseaworthy from going to sea. If, therefore, the Board of Trade were to exercise effectively the powers which they have obtained under the Act of 1873, the existing laws provide them with the means of accomplishing the objects which Mr. Plimsoll has in view. It seems to me that there is this advantage in the Act of 1873 as compared with an Act which would impose a universal load line and a universal classification in every ship, namely, that the shipowner, under that Act of 1873, remains invested with that personal responsibility which we all feel it is so important to maintain. Turning from legislation to administration I would urge as specially important an improvement of the organisation of the Board of Trade in its marine department. The care and supervision of the great mercantile marine of England is a vast and weighty charge, and it has no natural affinity whatever with the supervision of railroads and the numerous other subjects which are now comprehended within the administration of the Board of Trade. What I hope to see constituted ere long is a great marine department having a separate organisation which shall carry into effect, in a manner such as has never been hitherto attempted, the provisions of our existing legislation. I feel most strongly that the Board of Trade is not properly represented locally. I cannot myself rest satisfied that the staff at the different ports is altogether as efficient as it ought to be, and I regret that the Board of Trade has hitherto been unwilling to give to their staff at the outports that individual responsibility which I think they should have. Most certainly the scale of remuneration which has hitherto been thought sufficient is not, according to a business man's view of the question, at all adequate to secure for the public service the class of men that they should have. The point of insurance has already been referred to. It seems to me that if we could rectify what I conceive to be the inconsistencies of the law of insurance, we should be making a very important step in the right direction. My honorable friend has spoken of an improvement in the tribunals before which cases connected with the loss of life at sea are tried. That, I think, is a most important step. These then are the main points which should be attended to: to improve the constitution of the marine department of the Board of Trade; to remedy the inconsistencies of the law of insurance; and to improve the tribunals which have to deal with cases connected with loss of life at sea; and fourthly and lastly, it seems to me to be most important that we should improve the *personnel* of the mercantile marine. We have heard a great deal lately of plans for establishing additional training ships, and for increasing the efficiency of those which exist; and if the country does its duty in that respect, and if laws are passed which will tend to improve the discipline of the crews of our merchant ships, that will be a most important step. And we must not forget, in connection with this great question of the improvement of the *personnel* of the mercantile marine, that it is essential that we should have first-rate officers to command the ships. I very much doubt if there exists at the present time a proper system for the technical education of this most important profession. I believe that in recent years the officers of the merchant service have been deprived of some of the facilities which formerly existed for receiving a professional education. I believe that in former days there were a greater number of ships carrying midshipmen than there are now in the merchant service. It was only pointed out to me in a letter I received yesterday from Captain Trivett that there were facilities formerly at Greenwich School which do not now exist for the professional training of officers of the merchant service; I must say that, in our efforts to improve the professional education of the officers of the merchant service, we may reasonably

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claim some assistance from the Royal Navy. It is quite certain that the Royal Navy can provide a system of training for that superior class of young men whom I should like to see making the sea a profession, and that the Navy can afford to that class a training more suitable than it is possible to provide for them in the ordinary arrangements of the merchant service. The efficiency of the Naval Reserve would be increased, and the merchant service would be raised in discipline of the seamen; and the social standing of the officers, if the Royal Navy would undertake, to a larger extent than heretofore, to provide means for the professional training of young officers who should, after they have received their training in the Royal Navy, adopt the merchant service as their profession. I fear that I have already occupied the time of this Meeting at too great length. I am pleased to have been here; and I am quite sure that the attention of Parliament will be given in a very marked manner to the debates which take place at the annual gatherings of this Institution, and that what is said here will have an important influence on the legislation of the present Session.

Mr. E. J. Reed, C.B., M.P.: My Lord, I propose to speak very briefly upon this subject, because there are other interesting Papers to follow. I wish to avail myself of this opportunity of expressing my inability to concur altogether with the results of the Royal Commission Inquiry viewed from a professional standpoint. I am sure that I shall not be supposed to wish to speak for a single moment against the industry and ability brought to bear by the Royal Commission on this very difficult subject, but I wish to say that I do not think the Report of the Commission is satisfactory from a scientific point of view. I shall only illustrate that by reference to one subject, because the occasion does not afford opportunity for more. I simply take the manner in which the Commission have dealt with the question of load line. Now the Commission have laid down three propositions; first, that there is for every ship a line, beyond which she ought not to be loaded; they have laid down secondly, that the proper way of determining that line is not by the consideration of mere freeboard; and they have laid down thirdly, the proposition that the proper measure, or at any rate the most proper measure, the Commission could suggest, after hearing all the evidence, was the proportion of spare buoyancy such as has been recommended to-day. Having laid down those propositions the Committee drew these inferences. They said—not of course in these terms, but in substance—as there is for every ship a line beyond which she ought not to be loaded, we do not propose to recommend that such a line be fixed for any ship. They said, as freeboard is certainly not a proper measure for determining the degree of a ship's safety or otherwise, we recommend that a scale of freeboard be marked in every ship and made legislatively compulsive. They said, as we believe spare buoyancy is the proper thing to look to, we recommend that no scale of spare buoyancy should be marked upon the ship. And they gave a very curious reason for that. They said—Our reason for not recommending that a scale of buoyancy be marked is, that if you put a scale on the side of the ship, which does point out what is really the indication of danger in a ship, do you suppose we should be allowed to stop there? No, we should be obliged to follow it up with legislation to make it incumbent on shipowners not to load beyond a proper point. Therefore, the object of the Commission being to improve the safety of our sea traffic, they decided against doing the thing they considered proper; recommended the doing of the thing which they thought was not proper; and left out altogether, and proposed to do nothing at all with regard to legislative enactment as to the question of load line. Now that, my Lord, is my reading of the Report of the Royal Commission on the question of load line, and I think that whatever opinions may exist upon the subject generally, it will be be felt that those conclusions are scarcely

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satisfactory, and I for one am sorry to have to discuss in Parliament legislation based on recommendations which do not seem to me consistent. I quite admit that those views have grown out of the difficulty of the subject; but at the same time I think it proper in this Institution that somebody should rise and, in the name of independent thinking on this question, should express an objection to that mode of reasoning. I think it would be improper to enter more fully into other parts of the Royal Commissioners' Report, but I have thought it right, as a Member of this Institution, to make these comments. Mr. Wigram mentioned just now the impossibility of ships carrying boats which were sufficient to carry all their passengers at sea. I believe entirely that will be found impossible, and I believe also that in the Royal Navy in the days of the line-of-battle ships it was utterly impossible for the ships' boats to carry the whole of the crew, and I have never known that condition even to be considered. But I must say one word in modification of what Mr. Wigram said, because he seemed to infer that the simple fact of its not being necessary in the Royal Navy of itself made it entirely unnecessary in the mercantile navy. That I do not agree with, because we do not find that ships are lost in the Royal Navy in anything like the same proportion as they are in the mercantile navy. For instance, public attention has just at this moment been drawn to that fact by some friends of mine, from my having designed sixty-eight ships for the Royal Navy, and though they have put "foundered" against one, that is only one ship lost out of sixty-eight, and that foundered after having been run stem on into an iron vessel. Therefore, I think if sixty-eight of her Majesty's ships have cruised about without one disaster at sea, without a single casualty except the one I have mentioned, that the cases are not strictly analogous. Then I wish to explain, in deference to several questions put to me with regard to a point which is perfectly *à propos* to this Discussion and of some moment to us professional men. Notice has been put on the Paper in the House in my name, to the effect that I intend to propose in the Merchant Shipping Act the clause for imposing certain tests with regard to iron. I have been asked, and spoken to, and written to about it. There are several of my friends here who are particularly interested in the question, and I wish to explain that the clause on the Notice Paper was not drawn by myself, and was not seen by me before it was put there. It was put there by some energetic friend of mine, who perhaps a little exceeded his duty in doing it. I have, however, agreed to bring in a clause of that nature, because I believe that iron should be brought under legislative control in some degree. I did not hear the beginning of this Discussion, but I did hear the greater portion of Mr. Scott Russell's Paper, and I hope I may take the opportunity of thanking him for the clear manner in which he has drawn attention to some of the points which should lead to legislation in this matter. Mr. Scott Russell's Paper "On the Education of Naval Architects" led to serious and valuable action afterwards, and I think this Paper will be useful as a guide to those of us who are engaged in discussing this very important subject.

Mr. Charles Lamport: My Lord, I think Mr. Reed's criticism upon so much of the Report of the Royal Commission as refers to freeboard, very complete in itself, but it is a question that should be judged of, not partially, but in reference to the entire spirit of the Report of the Commission. The Royal Commission Report, if I understand it rightly, condemns a fixed load line, thinking there is greater effect in individual responsibility. They say, it may be well to mark a load line; it may be that an insufficient freeboard is an element of unseaworthiness; but they also say that the amount of that freeboard depends upon many considerations; it depends upon the form of the ship; it depends upon the cargo to be carried in that ship; it depends upon the voyage which that ship is to take; it depends also upon the time

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of year that the ship sails to make that voyage; and it also goes on to say in spirit if not in words, that all these are points which the shipowner alone is able to form an opinion upon, and therefore it is safer to leave the solution of this difficult question in his hands. If we pass a law, or recommend a law to be passed, to have a fixed load line marked on a ship, we take away from the shipowner all responsibility with regard to loading. It would be a line which would always be loaded down to, whereas an intelligent shipowner who wishes to keep up his character, would not under all circumstances, if left to himself, bring down his ship to one fixed load line. Looking at the question broadly, and following up what fell so very appositely from Mr. Wigram, allow me to call the attention of the Meeting to another point which was referred to in the Report of the Royal Commission. It will enable us to judge of the whole question before us—to know what it is we want legislation to take place about; because when we come to talk about loss of life at sea, and to listen to Mr. Plimsoll's sensational speeches as regards that, and see that he charges it, and that it is generally charged, to the peccancy of shipowners, I think that this question should be put on a right footing. I am obliged to quote from memory, but I think Mr. Samuda will bear me out in the figures which I will mention. Going back to 1847, and coming to 1872, a period of twenty-five years, there have been, as everybody knows, a great many lives lost at sea owing to numerous shipwrecks; but, Gentlemen, let it be borne in mind that the Board of Trade has examined this matter, and has stated in fact that so far as their inquiry has been made, and this is all the public can know about it, only 4½ per cent. of the lives lost during those twenty-five years are owing to the unseaworthiness of ships, and 69 per cent. are owing to causes which are directly attributable to carelessness in the navigation of those ships; that is to say, to the crews themselves; and the balance, with the exception of thirty-eight cases of shipwreck of which no record has been kept, were from causes unknown. They are in fact attributable to the dangers and difficulties which are inseparable from the navigation of the seas. Now what is it that is proposed?—The call is made for legislation, not to deal with this man or that man, not with those shipowners who are peccant and infected, as Mr. Plimsoll charges them, with the greed of gain, who want to send unseaworthy ships to sea so as to unduly make money, and who imperil the lives of their crews to get profit, but to subject the whole of the mercantile marine of this country—all shipowners, shipbuilders, and everybody connected with it—to a system of inspection, and a system of interference, which I hold will take away from them most essentially that responsibility which makes so large a proportion of them carry on their business in a way which is a credit to their names, to the class to which they belong, and to this country generally. Now, Gentlemen, this is a question really and truly of law, or no law—a question of inspection under Government enactment, or of leaving it to the responsibility of the owners. Mr. Scott Russell's able Paper I entirely agree with in principle, but disagree with when we come to details. Mr. Samuda, in his admirable speech, also condemns interference generally as a principle in law, but bye and bye he comes and advocates its application with regard to one or two questions, insurance amongst others. And Mr. Brassey, although he coincides, I believe, with the admirable Report made by the Royal Commission, does not hesitate to affirm a principle which I say lets in the thin end of legal interference, and that once done who knows where we are to stop? If once it begins, and if once you allow it in some degree and in some detail, where are you to draw the line? Now let us look back to the shipping legislation of the past. Let us go back for the last twenty years. I think it was Mr. Samuda who said something about deck loads. There was a law twenty years ago with regard to deck loads which could not be carried out, and it is impossible that the shipowner could carry out that law with regard to deck loads. If it were practicable I can only

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say that it would throw our timber trade into the hands of foreigners—our own men would go and ship in American vessels—in the ships that come from the Baltic, or other ships, and the only difference will be that our ships will not fly the English bunting, and that their names will not be in the Register of English owners. Deck loads will be carried still, and the only effect will be to drive the trade from the shipping of this country, and to put it into the hands of foreigners. Law has been tried with regard to tonnage. Mr. Scott Russell has told us what the end of that was, and that even now the traditional effect of it is interfering with the seaworthiness of our ships. Our ships are not built now as they ought to be, because years ago the Legislature interfered in such a way that shipbuilders and shipowners got the habit of building ships and sending them to sea in an unseaworthy form. Then law interfered with regard to chain cables. The Royal Commission reports upon that, that such interference has had a pernicious effect, and so it has, no doubt; and so it goes on abortively as regards boats and lights. My Lord holds up his watch, and I will sit down, but I wish merely to draw this line of distinction most clearly as a shipbuilder, as a shipowner, and as an underwriter—Do not let us lose sight of that which it has become an axiom to regard in all commercial matters. When the Government went to the Lyonese silkweavers, and asked them, "What can we do to legislate in your particular branch of business?" they replied, and it should be printed in letters of gold in every port in this country,—" Let us alone!"

Mr. C. W. Merrifield, F.R.S.: Mr. Lamport has rightly said that the key note of our Report is leaving the responsibility exclusively to shipowners, and not tacking it on the Government. I find in almost the last paragraph of it these words:—"We have been anxious throughout our Report not to "transfer responsibility from the shipowner to the Executive Government." That is the key note of our Report. We have carried it out in some points of detail to what some persons may consider extremes. We have remarked upon the present system of inspection of passenger ships, and have expressed a doubt whether even that was desirable, and had not better be sacrificed to the general principle of leaving the responsibility to the owner and shipper; we have made some remarks about compulsory pilotage, but in disapproval of it, because it tends also to interfere with the direct responsibility of the owner. Before going any further into the general question, I will answer some of the remarks made by Mr. Reed, and in doing so I hope you will understand that I am expressing the reasons why I felt myself justified in signing this Report, and I am not at all undertaking to interpret the opinions of my colleagues. In the first place, with regard to the load line depending on reserve buoyancy, I find the words of our Report are these:—"The information which we have obtained leads us to the "conclusion, that the settlement of a load line should be mainly guided by the consideration of the reserve "buoyancy." You will observe that a great deal depends upon the adverb "mainly." Then we go on to say, a little later, "That any rule of freeboard founded on surplus buoyancy gives to a vessel of "light scantling an advantage over a stronger vessel. Thus the inferior ship would by law be allowed "to carry the heavier cargo. Such an enactment would not contribute to the safety of life at sea." That, Gentlemen, was the reason why I not only did not recommend that any line should be drawn in compliance with that notion of surplus buoyancy, but why I did not even wish to see a scale of surplus buoyancy marked on the ship, because I knew that the immediate inference from that would be, "Oh, she "is only 5 or 10 per cent. out," or whatever may be considered sufficient to render the ship unsafe. Now, the other scale that I recommended to be put on the side of a ship, not only is of no use for that purpose, but cannot, in my opinion, be even subjected to that interpretation. I therefore willingly assented to that

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as a scale which would be useful to the Board of Trade Surveyor in enabling him to report the facts relating to the ship, and would not be liable to the misinterpretation of the other scale, which is, after all, more or less, the expression of a theory, and a theory which it is easy to apply in a very unsound manner, because when we come to the question of reserve buoyancy it opens up a great many things. Mr. Barnaby seemed to me to give the *reductio ad absurdum* to load line, in talking about an average base from which to measure the freeboard; and the difficulty is always staring us in the face, with ships not constructed with absolutely flush decks, as to what is reserve buoyancy and what is not. All those questions we should be let in for if we adopted such a proposal. My objection to the proposal which I see in Mr. Plimsoll's Bill, No. 2, and also in his Amendment to the Board of Trade Bill, is, that we shall be brought face to face with the merchants working one way to get every kind of structure on the deck recognised as surplus buoyancy, with all that strength and persistency which pecuniary interest gives, and the Board of Trade, perhaps weakly, resisting them. Those are the reasons why I, for one, was willing to sign the Report adopting advisedly the scale which would not indicate anything with respect to the safety of the ship. Now, upon the general question of the safety of ships, it seems to me that a great part of the difficulty which we are now brought face to face with is due to the over-tenderness of former legislation in favour of the investment of money in shipping. It was thought desirable to facilitate that, and the consequence is that we have not unfrequently this sort of thing forced upon our notice, that three or four men, having a little surplus capital to spare, and not finding themselves satisfied with any investment immediately open to them, think they will invest it in merchant shipping, and do so; and they look out some ship chandler in a small port, or some clerk in a bank, or somebody interested in some other little ship in the port, to undertake the management of the ship, to be their managing owner, and to keep their books. None of these parties know anything really about shipowning; and then the law, in order to encourage that sort of thing, stepped in and said, "You shall not be ruined by your own ignorance." I see around me here intelligent shipowners, I see both London men and country shipowners, who really know everything relating to a ship, from a rivet to a rope. Those men do occasionally lose ships, but if they lose them it is not from ignorance, it is not from parsimony, and it certainly is not from over-insurance, or any other of those examples of bad management which arise from a combination of ignorance of the business which the persons are engaged in with that rapacity which leads them to look only to the profit and loss account, and to consider that a good captain who requires a good equipment is a bad servant because he makes expensive demands. In fact, throughout the whole thing we have constantly been brought face to face with the fact that it is ignorance and not fraud which is the great enemy that we have to contend with. I think it may be that I attach too much importance to this from having been brought up in an educational department myself, but I think it will be found that defects in the construction are chiefly—although no doubt the result of the old tonnage law may have something to do with it—the results of ignorance. But at the same time it must be recollected that the persistence in that usage is in itself one of the effects of ignorance, and it does seem to me that ignorance is the great enemy with which we have to contend. I do not charge naval architects with ignorance. There are many of them here who certainly know more about their profession than I ever attempted to learn as an amateur, but I think it must be admitted that the number of shipbuilders who really have every detail of their ship worked out, and really make themselves acquainted with all its qualities in every possible way, is not very large. In fact, constantly, when I have been trying to get some information as to a particular ship and her displacement, I have found that there is no sheer draft in existence, and much less any other

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calculation. I think you will all admit that one of the commonest results of ignorance is a failure to understand the value of knowledge, and this is about as striking an example as I can give of it. With regard to detailed interference and the importance of not exercising it, I think I feel it very strongly; for, having been brought up in a Government department, I find there is always the tendency if you interfere at all to interfere more and more in detail, and to settle those details quite as much with reference to the convenience of the Office as with reference to the importance of the work to be taken in hand. I do not think I could have found a fitter example of the habit of interference in detail than in the proposal made in the Government Bill with respect to boats. To the best of my belief they are not only undertaking an impossibility, but unless they apply very liberally the discretionary powers given them they will actually render the ship unseaworthy by the precaution they have taken to save the passengers in case anything happens to the ship. Now it has happened to me to have had to save my life by swimming from a boat, but that is not the way that I like to save my life; I would much rather have kept the boat afloat. I, for one, entertain the same idea with regard to a vessel; and if I go to sea in a ship I would rather depend on good navigation keeping her afloat than on the boats. That seems to me to be a marked example of the danger we shall get into by anything like interference in details. I must say that I hope the Meeting will cordially join with me in the feeling that we have done right in being "anxious throughout our Report not to transfer the responsibility from the shipowner to the "Executive Government."

Admiral the Right Hon. the EARL OF LAUDERDALE, K.C.B.: My Lord, this Discussion has been carried on longer than is general, and I will not take up the time of the Meeting except by a very few words. Allusion has been made in the first place to the Report of the Royal Commission. It is a most admirable Report; but really, when we come to look at it, it tells us nothing new and recommends no means of dealing with the very points the solution of which we want to get to the bottom of. First of all they tell us that insurance is injurious, but they do not tell us how to avoid the insurance. Then I think they allude to the low freeboard as injurious; but they do not tell us what marks to put on the side, or how to avoid loss of life in any way. There are a great number of valuable remarks, but really it comes to this, that the Royal Commission merely tells you that you must legislate on the subject, and that it is a very difficult question indeed. Now with regard to Mr. Scott Russell's Paper I agree with Mr. Scott Russell in almost every point except as to the length of ships. I think he said that he could make a long ship quite as safe as a short ship. I do not venture to differ from him if she has a proportionate breadth, but I mean to say that a vessel that is twelve times as long as she is broad can never be made so safe under ordinary circumstances as a ship four times. But then it is said, "Oh, we will make her so strong that we can make her any depth." I say you cannot make her any length and go beyond a certain point of depth. If you have to go through the Suez Canal you are tied down to a certain depth. Therefore that is a point of weakness; and from my experience at sea with regard to these long ships, although you may measure the ordinary height of a wave, sometimes a heavy wave and a small wave, and a cross wave comes, and a long ship has not the same chance of rising to the sea as a short ship. Look at the number of steamers that have disappeared this last winter. Most of them were long ships. If the ship is a long ship and her decks are very strong and securely battened down, so that water cannot get in, she has a chance of floating; but otherwise the decks are swept fore-and-aft, and although you may keep the vessel afloat, unless every man is lashed to his post he will go overboard, and

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although the vessel may float there will be nothing else left in her. That is the case constantly with these long ships. Then there is another point that I think has been touched on by most of the gentlemen who have spoken—that is, that they would leave the question of the safety of the vessel entirely in the hands of the owners, and the shipbuilder has nothing to do with it after he is paid. I quite agree with that if you will do away with insurance and leave the responsibility of the value of the ship entirely on the shipowner—leave it all to him; but as long as he can hedge off and have no responsibility I think it is necessary for Government to interfere. Then with regard to the mark on the ship's side, I agree with Mr. Scott Russell in thinking there ought to be a mark. The mark could be arranged by shipbuilders and naval architects. For instance, by a Society like this through Government; and there might be a mark on all vessels—I do not mean to say that there should be a hard-and-fast mark—so as to do away with any legal responsibility; but that no vessels should go to sea without this mark, which is intended to indicate at what depth she would be safe. Then it is contended that you cannot fix that mark because the ship may be going on a fine weather voyage or a bad weather voyage, but no man can tell what weather he will meet when he gets to sea. One half the ships that are lost are lost in hurricanes and in bad weather when they never expected it. To leave it to a man to judge how deep he is to load his vessel in the course of the voyage I consider is not safe.

Captain Sir J. Heron Maxwell, Bart., R.N.: My Lord, I have not the great honour of being an Associate, but I have been invited to attend, which invitation I most cheerfully accepted. Having had the still greater privilege of presiding over five different meetings relative to Sir Charles Adderley's Bill, and having likewise the honour of being Chairman of the Committee appointed to watch over that Bill and to make such suggestions upon it and alterations in it as we might think prudent, I only wish to say one or two words merely to express the high satisfaction and gratification which I felt at the remarks of my honourable friend the Member for Hastings, Mr. Brassey, relative to the *personnel* of the mercantile navy. It is a matter on which I, as a seaman, am more entitled to have an opinion than upon that of shipbuilding; but a more important subject connected with the mercantile navy and the nation cannot be entertained or conceived than that of the efficiency of the seamen of that navy. I remarked some time ago, and I believe it is the case, that our seamen are not up to the old standard. I was just in time to hear the concluding words of my noble friend, Lord Lauderdale, in the House of Lords the other night, when he said we have not now in the mercantile navy the same class of men that we had thirty or forty years ago. I think that is generally accorded. There are various opinions as to the reason for that decline, but certainly it is the case, and, therefore, I think the great object now is to improve the *personnel* of the mercantile navy. As to that, I think there are some suggestions in the Government Bill which are most valuable. Some of them, I think require alteration, but upon the whole I think the Bill will have a very good effect indeed with regard to what we so much want. There is a suggestion, I think, which was made by Mr. Brassey that he should wish to see the Marine Department of the Board of Trade somewhat altered and amended. That also I entirely agree with, and I trust that the suggestion will meet the approbation of both Houses of Parliament, and that it will be carried into effect. Then as to the safety of the ships something was said, but while I fully admit that the safety of the seamen entirely depends on the construction somewhat of the ships, no less does the safety of the ship itself depend on the efficiency of the seamen. Therefore, I think the great object is, if we can, to improve in any way by education and by every other means the *personnel* of the mercantile navy, both as regards seamen and also as regards officers, which is not a whit less

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important. I think if that were effected a very great service would be done to the nation in general. Now, one single word about the boats. With regard to what fell from Mr. Wigram, what has suggested itself to me and to my brother officers sitting near me is, that even with ten boats which, I think, is the largest umber proposed to be supplied to ships in the mercantile marine or our own ships, to say that we have boats enough to save the lives of all the crew on board, in effect is one of those statements which are sometimes made, but the carrying out of which is practically impossible. I do not think that we are yet living in such a Utopia that we can avoid some risk. If people will go about on the wide waters they must incur some risk or other, and the great thing is to let that risk be, as far as human means can make it, as slight as possible. I perfectly agree with my friend, Mr. Merrifield, who said that he would far rather stick to the boat than have to swim from the boat. I make these few remarks on account of the position I am holding just now as Chairman of the Committee watching over that Bill, of which my honourable friend is a Member, and for the purpose of making such suggestions as have occurred to me. In conclusion, I would only say I shall be most happy to become a Member of this noble Institution, which I have been invited to do.

The CHAIRMAN: I think you have supported me, or at least have agreed with me, in considering that the great interest and importance of this subject warranted the course which I have taken of allowing this Discussion rather to exceed the limits usually fixed for our Discussions. But I cannot allow this Discussion to terminate without expressing the very great satisfaction with which I have heard not only the able Paper of my friend Mr. Scott Russell, but the very able and practical Discussion to which that Paper has given rise. I fully anticipated that we should have an able Discussion, and I must say that I do not think I have ever heard in this room a Discussion more creditable to the ability of the gentlemen who have conducted it. And allow me emphatically to add, that which in substance has been already said this morning, that I do not believe there was ever a moment when such a Discussion would have been more important or more interesting. But we must not suppose that we can rest on our oars with regard to this matter. The dangers of the sea are greater than they ought to be, and I believe no practical man will deny it. I have had placed in my hands an extract from a French publication called the *Veritas*. I am not familiar with it myself, but I believe it very much corresponds with Lloyd's Paper in this country, and I find there recorded the fact that in the month of January which has just passed there have been not less than two hundred and eight wrecks, eighteen of which were steamers; and I speak under correction if I am mistaken, but I believe that if I did not limit myself to the month of January, but went back four months from this day, I should find that there has been an unusual amount of loss of iron steamboats. Now, Gentlemen, my belief is—and of course I speak as an unprofessional man—that if iron steamboats were properly constructed, built of proper metal, and properly handled, that a casualty to an iron steamer would be almost an impossibility. I think the facts which we have heard prove that this is one of the most interesting subjects of the day, and I must express my own great pleasure in having heard it treated in so satisfactory a manner as it has been. I would now ask my friend Mr. Scott Russell, before we proceed to the next Paper, if he wishes to make any observations in reply.

Mr. JOHN SCOTT RUSSELL, F.R.S.: My Lord, I have hardly anything to say, except that I am extremely gratified at the very kind, considerate, and thorough discussion which this subject has received. There are a good many gentlemen here who understand this matter thoroughly, and whom I should have wished to have heard express their opinions, but as the subject comes on again to-morrow evening, I think

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a great deal of what might now be said would probably be more appropriately said then. There is only one little point on which I wish to make a remark, because it is a point which I did not touch upon, namely, the question of boats. It is a very serious question, but I adhere to the opinion that we had better render the boats unnecessary than multiply their number, because one of my finest ships was once very nearly lost by a not extremely experienced captain trying to save his boat at the expense of his ship. Now I beg to say that it is in the power of the English shipbuilder—and I appeal to all here—to build and arrange for you iron ships which practically are utterly unsinkable, and the only condition demanded is, that you shall want to have them. If you want to have them, and take a little trouble, and go to a little more cost, and let us do what we know to be desirable, then you will get perfectly unsinkable ships. I must thank you, Sir, for what you have so kindly said, and also my brethren here, who have co-operated with me, I hope, in making plain what are the things in which we think the Legislature might justly occupy itself, and what are the things which we think the Legislature would do more harm than good by meddling with. I think we have done our duty, and I now leave the Legislature to do theirs.

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ON THE LOAD-DRAUGHT OF STEAMERS AND SAILING VESSELS.*

By W. W. Rundell, Esq., Secretary to the Underwriters' Registry for Iron Vessels, Associate.

[Read at the Sixteenth Session of the Institution of Naval Architects, 18th March, 1875; the Right Hon. Lord Hampton, G.C.B., D.C.L., President, in the Chair.]

Since 1870, when I first addressed you upon this subject, public interest in it has not abated, but seems rather to culminate at the present time. I offer no apology, therefore, for again returning to this topic, and asking space for a fourth and final Paper on load-draught.

My object now is to make a few additions to the history of the subject; to generalise, to some extent, the details I have already put before you; and, finally, to deduce from them, for your consideration, a Table of Freeboard indicating spare buoyancy in terms of registered tonnage, which shall be applicable to all kinds and sizes of sea-going vessels.

Circumstances almost compel me to reiterate what will become apparent to any one who will carefully go into the history of the subject, that the scales of freeboard which still govern our practice were not the result of science, were not originated by naval architects or shipbuilders, but came directly from the every-day experience of a number of underwriters' surveyors, who, during many years, had been engaged in the surveying of the hatches and cargoes of inward vessels, and the stowage and loading of the outward bound.

In my first Paper I showed that the scale in use at Liverpool, about twenty years ago, was a sliding one, varying according to the depth of hold of the vessel. Also that the proportion of 3 inches to the foot, required for vessels of about 20 feet depth of hold, when applied to iron sailing vessels, meant cutting off a part of the vessel for spare buoyancy equal to 30 per cent. of the registered tonnage under deck, and that there was a very easy mode of ascertaining the freeboard represented by this proportion when the registered particulars of the vessel were known.

* Received 15th March, 1875.

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A little consideration will show that, if 3 inches to the foot is equivalent to 30 per cent. of registered tonnage for spare buoyancy, 2 inches to the foot must mean 20 per cent.; 2½ inches to the foot, 25 per cent.; and so on for other per-centages. Further, that this sliding scale, as applied to wooden vessels, did not favour the smaller vessels so much as at first sight might appear to be the case; and that as regards the larger vessels, their relative want of strength was not unduly estimated. The scale, it must be remembered, is founded on an inside measure, while the outside measure or buoyancy is relatively much larger in the smaller than in the larger vessels. The average sheer of the ship is also taken into account, and this is also proportionately greater in small vessels; affording additional proof that the sliding scale may be comparatively uniform when expressed in terms of buoyancy.

Aided by this explanation, I ask you to again look at the old scale for wooden ships, and the alteration which was made in it in 1869, to suit the practice prevailing at that time in Liverpool in regard to the loading of iron vessels. Please remark that the rule did not make, but only recorded, the practice then prevailing; also bear in mind the relation, which has been pointed out, between the figures showing the proportion of inches per foot for freeboard, and the same figures as approximately indicating per-centages of buoyancy.

In order to compress a portion of the scales of freeboard into the size of an ordinary page, I omit in the following Synopsis all the columns of figures except those relating to depths of hold for even numbers of feet.

The first part of the annexed Synopsis shows an abstract of the scale in use at Liverpool to my knowledge about twenty years ago, and to be found in full at p. 44 of our *Transactions* for 1870. At p. 46 of the same volume will also be found in full the scale for iron vessels, which is shown in abstract in the second part of the Synopsis. It is a modification of the first part of the Table, and was made at my request rather more than six years ago to represent the practice then approved of in Liverpool for the loading of iron sailing vessels. These scales, or copies of them, were the only ones of the kind in use at the time I name. Proofs of the 1869 reprint were sent round the country to various experts for their criticism, but I do not remember that any objection was made to them from any quarter.

In 1873 the Committee of Lloyd's Register were induced to move in the same direction, and in July of that year their Chief Surveyor presented to the Royal Commission on Unseaworthy Ships, which was then sitting, very elaborate Tables, giving freeboard not only for sailing vessels, but for steamers also, a thing which, so far as I am aware, had not previously been attempted. The Paper I had the honour to

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bring before you in March of that year only proposed a mode of marking the sides of steamers so as to show freeboard in per-centages of tonnage, and did not attempt to say what the per-centage should be. A mode of assessing the erections above the principal deck, which I had previously suggested (*Transactions*, Vol. XIV., p. 21), was practically adopted by Lloyd's Registry in their new scheme.

Immediately on receipt of a copy of this Table, I looked out the freeboard allotted to medium vessels, and selecting for this purpose the co-efficient of fineness ·67, I found the figures now given in the third section of the following Synopsis, and was gratified to observe that they were identical with, or only differed to a very small extent from the Liverpool Scale.

This is not only a remarkable result, it is a very important one, and will no doubt be very gratifying to those who say there is no essential difficulty in fixing a fair load line. That you may fairly estimate the significance of this result, I make the following extracts from the evidence of Mr. B. Martell—one of our Council, and Chief Surveyor to Lloyd's Registry—from the Report of the Royal Commission, to show how his Table was obtained. (11,203) "It was prepared by myself and my assistants at "Lloyd's Register." (11,204) "We wrote to all the shipowners and shipbuilders who we "thought could furnish us with information, and from it we have framed this Table, "which I think would apply to all forms of ships." (11,206) "I have made very large "enquiries to verify it by asking them (shipowners and others) what they consider a "fair freeboard, and likewise from the particulars of hundreds of ships which we have "obtained. We have compared the freeboard obtained in this manner with the freeboard "generally accepted, and find the result satisfactory." (11,208) "The freeboard in the "Table agrees with the freeboard given generally by shipowners whom you would "like to follow." (11,209) "We have only completed it (the Table) this very day." (July 29th, 1873.)

This evidence very emphatically supports my statement that freeboard is not a matter of theory, but of practice, and completely proves that the practice recorded in the Liverpool Scale of 1869 was essentially the same which was general all over this country in 1873, "by shipowners whom you would like to follow," as ascertained by extensive enquiries made by the officers of Lloyd's Registry during a period of six months. Part III. of the Synopsis gives, in a compendious manner, the corresponding lines from the improved Tables presented to this Institution by Mr. Martell last Session, while Part IV. gives an abstract of the freeboard for medium steamers. The difference between the original and the amended Table for steamers is very small, but in that for sailing vessels it is so much as to call for some remark. The explanation may, perhaps,

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Synopsis of Freeboard Scales, &c.

Part I.—Wood Sailing Vessels.											
Depth of hold in feet	8	10	12	14	16	18	20	22	24	26	28
Inches per foot depth of hold for freeboard	2·0	2·2	2·4	2·6	2·8	3·0	3·2	3·4	3·6	3·8	4·0
Freeboard in feet and inches per Liverpool scale	1 4	1 10	2 5	3 0½	3 8¾	4 6	5 4	6 2¾	7 2½	8 2¾	9 4
Part II.											
Freeboard for iron vessels in feet and inches, Liverpool scale, 1869	1 4	1 10	2 4	2 10	3 4	4 0	4 9	5 7	6 6	7 6	8 6
Inches per foot depth of hold to correspond	2·0	2·2	2·3	2·4	2·5	2·7	2·9	3·1	3·3	3·4	3·6
Part III.—Iron Sailing Vessels.											
Freeboard, Mr. Martell's scale, July, 1873, co-efficient ·67 ...	1 4¾	1 10	2 4¼	2 9¾	3 5½	4 0¾	4 9	5 5	6 3¼	7 3¼	8 4¼
Freeboard, Mr. Martell's scale, March, 1874, co-efficient ·67	1 6½	2 1	2 8	3 2½	3 9½	4 4¼	4 11½	5 6½	6 3½	6 11	7 8¼
Inches per foot depth of hold to correspond with latter ...	2·3	2·5	2·7	2·8	2·9	2·9	3·0	3·0	3·2	3·2	3·2
Per-centages as per Table, for July, 1873	22 to 27½					27½ to 30				30 to 32	
And for March, 1874	20 to 27½					27½ to 30				30 to 32	
Part IV.—Steamers.											
Freeboard for steamers, Mr. Martell's scale, July, co-efficient ·67	1 4½	1 9	2 0¾	2 5¾	2 11½	3 7	4 2½	5 0¾	6 0¾	7 1	8 3½
Freeboard for steamers, Mr. Martell's scale for March, 1874, co-efficient ·67 ...	1 4½	1 8½	2 0¾	2 5¾	3 0¼	3 7	4 2¾	4 11½	5 9	6 8	7 9½
Inches per foot depth of hold to correspond with latter ...	2·1	2·1	2·1	2·1	2·2	2·4	2·5	2·7	2·9	3·1	3·3
Per-centages given in Table for July, 1873	22 to 25						25 to 27½		27½ to 30		30 to 33
Per-centages given in Table for March, 1874	20 to 25					25 to 27½			27½ to 30		30 to 33
Difference between freeboard for sailing vessels and steamers by July Tables, 1873	− 0¼	− 1	− 1½	− 4	− 6	− 5¾	− 6½	− 4¼	− 2½	− 2¼	− 0¾
Difference between freeboard for sailing vessels and steamers by March Tables, 1874 ...	− 2	− 4	− 7½	− 8¾	− 9¼	− 9¼	− 9¼	− 7	− 6½	− 6½	+ 1¼
Latter difference converted into per-centage of freeboard for sailing vessels	−11	−18	−22½	−23	−20	−20	−14¾	−10½	− 8½	− 3⅛	+ 1½
	Average 13½ per cent. of freeboard or about 4 per cent. buoyancy.										
Difference in the inches per foot depth of hold scales ...	− ·2	− ·4	− ·6	− ·7	− ·7	− ·5	− ·5	− ·3	− ·3	− ·1	+ ·1
	Average ·4-in. per foot.										

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be found in the following words in the Paper introducing the improved Freeboard Tables to this Institute:—"The Tables already issued have been slightly modified in "those now submitted, in accordance with more matured experience and larger "information relative to some types of vessels." It is, however, difficult to suppose that the practice of shipowners had changed even thus much in so short a time, especially in the direction which the change in the Tables would indicate, and I shall presently have to suggest another reason for the change.

As regards the scale for steamers, it will be observed that it resembles that for sailing ships at the two extremes, and gradually differs towards the middle to the extent of 7 per cent. of the vessel's capacity, the average difference in favour of the steamer being about 4 per cent. My own experience rather shows a general practice in cargo steamers of all sizes to load at least 5 per cent. of capacity deeper, when leaving port, than sailing vessels of the same depth of hold; and in some kinds of cargo steamers even more than this; but my experience is comparatively local, and I cannot pretend to have made so many or such extensive inquiries as to the loading of steamers as the officials of Lloyd's Registry, though I may possibly have collected as much or more information as to their forms and displacements.

Having availed myself of the valuable support which these new Tables of load-draught give to my earlier proposals for expressing freeboard in terms of registered tonnage, I now propose to show—and I trust that the author will forgive me—that these elaborate Tables, as a whole, are almost useless; the result, apparently, of a misconception, except as regards the small entry which appears near the top of each of the fifteen pages, and which I now extract in full, as follows:—

Sailing Vessels.			
July, 1873.		March, 1874.	
Depth of Hold.	Per-centage.	Depth of Hold.	Per-centage.
ft. ft.		ft. ft.	
7 to 16	22 to 27½	7 to 16	20 to 27½
16 „ 25	27½ „ 30	16 „ 25	27½ „ 30
25 „ 28	30 „ 32	25 „ 28	30 „ 32
Steamers.			
		ft. in. ft. in.	
7 to 18	22 to 25	7 0 to 14 3	20 to 25
18 „ 22	25 „ 27½	14 3 „ 22 0	25 „ 27½
22 „ 26	27½ „ 30	22 0 „ 26 0	27½ „ 30
26 „ 31	30 „ 35	26 0 „ 28 6	30 „ 33
		28 6 „ 31 0	33 „ 35

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In this small compass lies the utility of the whole, for if these be correct with them and the registered particulars of any vessel, we have all that is wanted to ascertain the freeboard. The changing these per-centages into "co-efficients of fineness" is so much lost labour, as the same or fewer figures will, without the use of any Table, give practically the same results. To convert tonnage into "co-efficients of fineness" for this purpose is like converting sovereigns into half-crowns or shillings, and fancying you have more money. The potency of the method is contained in the registered tonnage of the vessel, and not in the co-efficient. This may be illustrated as follows:—

$$\frac{\text{Registered Tonnage}}{\text{Length} \times \text{breadth} \times \cdot 8} = \left\{ \begin{array}{l} \text{Freeboard in decimal parts of a foot representing} \\ \text{1 per cent. spare buoyancy.} \end{array} \right.$$

This gives us terms of freeboard at once. Mr. Martell's operation is as follows:—

$$\frac{\text{Registered Tonnage}}{\text{Length} \times \text{breadth} \times \text{depth}} = \left\{ \begin{array}{l} \text{A co-efficient of fineness which by the use of a} \\ \text{certain Table will indicate freeboard.} \end{array} \right.$$

Without the Table the co-efficient indicates only a mode of comparing vessels of the same length, breadth, and depth, but of different capacity, and for this purpose alone does the term "fineness" properly apply. It is obvious that we may double the length of a vessel, and halve the breadth or the depth, and though we still get the same "capacity" and the same co-efficient, there is a very different kind of "fineness."

It is fallacious, therefore, to suppose that the Table takes the *proportion* of different vessels as regards length and depth into account, except to a very limited extent. For absolute length it makes no provision. These defects are the more remarkable as the author seems unconscious of them, and charged me at the last Meeting with not properly appreciating absolute length.

Another defect which should be noted is that neither in Mr. Martell's evidence before the Royal Commission, nor in his Paper of last Session does he say how he cuts off the spare buoyancy represented by the per-centages given in the Table. The following are extracts bearing on this point. "How do you arrive at your load line?—"By obtaining approximately a means of cutting off in an easy manner from vessels of "different forms and dimensions an amount of spare buoyancy, in conformity with the "practice of shipowners generally of high standing. This is the first indication that I "am aware of a Table of freeboard being based on sound principles where it can be "applied to ships afloat as well as ships building."—*Report*, &c. (11,201). "The only "novelty introduced is a ready means of cutting off approximately in ships, already "built and afloat, the per-centage of spare buoyancy desired. The mode adopted is not "strictly accurate. . . . . ."* I have sought in vain for this "novelty." Could

* *Transactions* for 1874, p. 103.

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it be obtained it would probably account for the singularly large differences between the Tables of July and those of the following March, which are now to be brought to your notice. Differences indicating, not an alteration in the practice of shipowners, but apparently new ideas on the part of the compilers of the Table.

The registered tonnage, under deck, of a fine and full vessel, of the same length, breadth, and depth of hold, will differ by about 15 per cent. If we, therefore, select co-efficients ·60 and ·75 to represent these extreme cases, it will be evident that the tonnage and carrying power of the latter vessel will be one-fourth more than that of the former. It is evident, too, if freeboard is regulated by a per-centage of registered tonnage for buoyancy, it will also vary as these co-efficients vary, and that the buoyancy for co-efficient ·75 will be one-fourth more than that for ·60. Now, when per-centages of buoyancy are converted into freeboard, as is the case in these Tables, it is the net freeboard after an allowance has been made for the buoyancy contained in the sheer and round of deck of the vessels. The freeboard represented by ·75, instead of being exactly one-fourth more than that for co-efficient ·60, like the buoyancy, will, therefore, be rather more than one-fourth, or 25 per cent. greater. An example will make this clear. Suppose the tonnages to be respectively 400 tons and 500 tons, and that so much as 50 tons will in each case be represented by sheer and round of deck, this will leave 350 tons and 450 tons, respectively, to be represented by Table freeboard. That is, the freeboard for co-efficient ·75 will be 28½ per cent., instead of only 25 per cent. more than the freeboard for co-efficient ·60. Now, this increase is always more than enough to counterbalance any causes of difference acting in the opposite direction. Consequently, we are quite safe in asserting that the differences of freeboard ought, at least, to be in proportion to the increase of tonnage in vessels of the same linear dimensions, but having larger capacity. Let this test be now applied to Mr. Martell's Tables for depth of hold 8 feet, 18 feet, and 28 feet (*see* next page).

The differences, it will be observed, are always less than required by the difference of tonnage, although the March Table shows a considerable improvement on that for July. The change cannot, I think, be fairly attributed to a large difference in the practice of shipowners; and the explanation, that they arise from "more matured "experience and larger information respecting some types of vessels," will scarcely be accepted in any sense which is complimentary to the staff of Lloyd's Register.

I will only call attention to one other matter, which is illustrated by the Synopsis, and the other extracts which have now been made. It relates to the connection which exists between freeboard, as measured by inches and tenths per foot of depth of hold,

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and freeboard as measured by per-centages of registered tonnage; the same figures serving for each, by altering the place of the decimal point. On the whole, this is sufficiently shown by the medium co-efficients in the Tables; but, at their two extremes,

8 *feet Depth of Hold.*						
	Sailing Vessels.			Steamers.		
Co-efficient.	July Table.	March Table.	Difference.	July Table.	March Table.	Difference.
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	in.
·60	1 4½	1 6	0 2	1 4½	1 4	0½
·75	1 4¾	1 7¼	0 2½	1 4¾	1 5	0¼
	Difference per Cent.			Difference per Cent.		
25	1½	7	...	1½	6	...
18 *feet Depth of Hold.*						
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	in.
·60	3 10	4 0	0 2	3 3½	3 3	0½
·75	4 4½	4 9½	0 5	3 10½	4 0	1½
	Difference per Cent.			Difference per Cent.		
25	14	20	...	18	23	...
28 *feet Depth of Hold.*						
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	in.
·60	8 0¾	7 0¼	1 0½	8 0	7 5	7
·75	8 7½	8 5½	0 2	8 5¾	8 10	4½
	Difference per Cent.			Difference per Cent.		
25	7	20	...	6	19	...

we have this singular result, a decreased per-centage at the beginning of the March Table is accompanied by an increase of freeboard; at the end of the March Table, the per-centage remains the same as in that for July, while the freeboard is reduced by more than a foot!

Having now pointed out that Mr. Martell's extensive Tables, so far as they relate to vessels of medium form, are almost identical with the Liverpool Tables, which were printed in our *Transactions* for 1870; that, for vessels which vary from medium proportions and tonnage, the proposed freeboard varies neither with the co-efficients for tonnage nor with the per-centages placed towards the top of each page; that the novel mode of cutting off a definite proportion of the ship for spare buoyancy, mentioned so prominently, has nowhere been described; and that the Tables do not provide for

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absolute length of vessel, which, according to their author is a necessity, it will probably be conceded that they do not exhaust the subject, and that room yet remains for further discussion.

I venture, too, to think that some of the suggestions made in my previous Papers still remain intact, and that others may be so extended and improved as to be made generally acceptable.

Among the former I include the mode of cutting off a fraction of the upper part of a vessel to represent any given proportion of her registered tonnage. The marking amidships on the side of a vessel a scale to show spare buoyancy. The mode of adapting this to various types of ships.

Among the latter are the following:—In my Paper for 1873 I suggested that the per-centages should be marked at each foot interval of a vertical scale, and I showed how this was to be done with a great amount of exactness and with very little difficulty. Considerations which are set forth in my Paper for 1874, and "more matured "experience," show me that by far the most simple plan is to mark all vessels with the same figures, namely, the 10, 20, and 30 per cent. marks only, and to indicate the 5, 15, 25, and 35 per cent. marks by a short horizontal line. In this form there is reason for believing that it will be introduced by the Board of Trade into the new "Merchant "Shipping Amendment Acts Bill," in conjunction with a scale of feet for measuring freeboard in the usual manner. I am proud to acknowledge that this is very much due to the publicity which my scheme has obtained through this Institution.

In connection with this per-centage scale there is a moot point, which I hope will receive a thorough discussion at the close of this Paper. Should the per-centage marks show the actual buoyancy of the vessel which lies between the water level and the surface, all fore and aft, of the principal deck? Or, should it represent only the buoyancy of the vessel between the water plane and a parallel plane at the height at side amidships of the principal deck? The term "principal" deck is intended to describe the uppermost complete deck which is not an awning or a spar-deck. It is described in the new "Merchant Shipping Bill" as the deck to which "full scantlings "are carried." It would be a great convenience if this deck, in all cases, were made the Act of Parliament "tonnage deck," a term which is now most uncertain in its application. The "tonnage deck" is described as the second deck from below, but it varies in sister vessels according to the absence or presence of a "laid deck" on the lower tier of beams. In some cases the "tonnage deck" actually becomes a spar or awning deck.

Another point which will bear discussion is this:—Supposing that the per-centage marks represent either of the above facts, and also that there exists in the vessel

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erections above the principal deck, which duly qualified experts consider are entitled to make a reduction in the freeboard of the vessel, will it not be better to move the scale bodily up the ship's side a space equal to the reduction, rather than to select a smaller per-centage mark for showing the proper loading of the vessel? The former was advocated in my Paper for 1873 (*Transactions*, Vol. XIV., p. 21). By it the per-centage marks, at fair load-draught, would be more nearly the same in vessels of similar strength.

Up to the present time I have dealt with the subject of my Papers only on general grounds, as it appeared to me that, in respect to steamers, there was a lack of information as to the practice of prudent owners in the loading of their vessels. I now go a step further, and offer for your consideration a Table intended to represent a fair load-draught for all kinds and sizes of sea-going vessels. In it I have adopted the old practice of making an allowance for average sheer and round of deck, though I prefer the plan which would make the per-centages more uniform.

I distinctly offer the Table for consideration, and not as absolutely correct; though, as far as I can ascertain, it fairly represents the deepest loading of those "shipowners "whom you would like to follow." The Table is so constructed as to admit of being altered to a large extent, without increasing its size or changing its form, by a different placing or a difference of interval in the figures forming the first two columns.

It will be seen by this Table, which is intended for sea-going vessels, that the amount of buoyancy is made to depend not alone on tonnage, but also on classification, and that it is made to increase both with the actual length and with the relative length of the vessel as compared with her depth. The reasons for this arrangement are, firstly and chiefly, that practical men, and those who have been in command of long vessels, say that it is necessary to do so; secondly, because long vessels are not proportionately so strong as vessels of medium dimensions, nor are low-classed vessels so strong as high-classed ones.

For steamers the Table must be entered in the column headed "Length of "Steamers," on the line in which the figures correspond most nearly to the vessel's registered length. For sailing vessels it enters similarly in the column headed "Length of Sailing Vessels." The required spare buoyancy will be found in the column indicated by the figures showing the proportion of the vessel's length to her depth. The proportion of length to depth for iron vessels is given at the top of the Table, that for wooden vessels at the bottom of the Table.

To convert the proportion of spare buoyancy thus obtained into freeboard, as usually measured in feet and fractions of feet—first, divide the registered tonnage under

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TABLE FOR ASCERTAINING THE PROPORTION OF REGISTERED TONNAGE WHICH SHOULD BE ALLOWED FOR SPARE BUOYANCY OR FREEBOARD BELOW THE LEVEL OF THE DECK AT SIDE OF SHIP AT MID-LENGTH OF VESSEL FOR OVER-SEA VOYAGES.

The main deck or the deck to which full scantlings are carried is to be taken as the deck to which this Table refers. An allowance for an average amount of sheer and round of deck is already made in this Table. If there is much more than the usual amount of sheer or round of deck, 1 per cent may be allowed for each, *i.e.*, take one or two columns to the left of the one which corresponds to the proportion of the vessel's length to depth.

Length of Sailing Vessels.	Length of Steamers.	FOR FIRST-CLASS IRON STEAMERS AND FIRST-CLASS IRON SAILING VESSELS. Proportion of Registered Length to Registered Depth.												
		8	9	10	11	12	13	14	15	16	17	18	19	20
Feet.	Feet.	Proportion of Registered Tonnage for Spare Buoyancy of Freeboard.												
	160	15	16	17	18	19	20	21	22	23	24	25	26	27
	180	16	17	18	19	20	21	22	23	24	25	26	27	28
	200	17	18	19	20	21	22	23	24	25	26	27	28	29
	220	18	19	20	21	22	23	24	25	26	27	28	29	30
	240	19	20	21	22	23	24	25	26	27	28	29	30	31
100	260	20	21	22	23	24	25	26	27	28	29	30	31	32
115	280	21	22	23	24	25	26	27	28	29	30	31	32	33
130	300	22	23	24	25	26	27	28	29	30	31	32	33	34
145	320	23	24	25	26	27	28	29	30	31	32	33	34	35
160	340	24	25	26	27	28	29	30	31	32	33	34	35	36
180	360	25	26	27	28	29	30	31	32	33	34	35	36	37
200	380	26	27	28	29	30	31	32	33	34	35	36	37	38
225	400	27	28	29	30	31	32	33	34	35	36	37	38	39
250	425	28	29	30	31	32	33	34	35	36	37	38	39	40
275	450	29	30	31	32	33	34	35	36	37	38	39	40	41
300	475	30	31	32	33	34	35	36	37	38	39	40	41	42
FIRST-CLASS HARD WOOD VESSELS. Proportion of Registered Length to Registered Depth				8	9	10	11	12	13	14	15	16	17	18
FIRST-CLASS SOFT WOOD VESSELS. Proportion of Registered Length to Registered Depth				...	...	8	9	10	11	12	13	14	15	16

For second-class vessels take the second column to the right hand of that selected for first-class vessels.
For third-class vessels take the fourth column to the right hand of that for first-class vessels.
For composite vessels take the column next to the right of that for iron vessels according to class.
To apply the Table to vessels with awning, or spar decks, break decks, long poops, &c., *see* Examples.

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deck by the registered length multiplied by four-fifths of the registered breadth of the vessel—this will give, in decimal parts of a foot, the freeboard which corresponds to 1 per cent. of the registered tonnage. The division need not be carried beyond a result of three figures. Next, multiply the figures thus obtained by the figures in the Table which stand opposite to the vessel's length, and which are also in a line with the figures corresponding most nearly to the proportion of the length to depth of the vessel.

When great accuracy is wanted an interpolation may be made. Thus, if the proportion of length to depth is 12·6, instead of taking the figures under 13 depths for the multiplier, the figures under 12 depths may be taken, with the addition of ·6. Again, if the vessel has very much "spread" or very much "tumble home" aloft, the column to the right or the column to the left of the ordinary one may be selected; but, as a matter of fact, ships have about the same displacement per foot of depth for that part of the vessel which is usually above water. This precaution will, therefore, be seldom needed.

The following examples will show the ease with which the Table is applied to flush-decked vessels, when their class and their registry particulars are known.

These examples will show that, for flush-decked classed vessels, there is no difficulty in at once applying the Table; but the registry books give no indication of the strength of deck erections which is sufficient for the application of the Table to them. It is well known, for instance, that the term "awning deck," used by one registry, is applied in many cases to decks which are stronger than those termed "spar decks" by other registries. It is also known, that such erections as break decks, long poops, raised fore decks, &c., have very different degrees of strength in different vessels. Again, there may be erections which measure largely for tonnage, and have openings in them which render them useless for buoyancy. Hence it becomes necessary that any allowances to be made for deck erections should be made only after actual inspection, and by competent experts.

	Kind of Vessel.	Registered Tonnage under Deck.	Registered Dimensions.	Proportion of Length to Depth.	Buoyancy Mark per Table for "Fairly laden."	Freeboard in Feet.
No. 1.	Iron sailing ship, first class ...	510	165·4 × 27·8 × 17·5	9·5	26	3·54 = 3 6
„ 2.	Iron sailing ship, first class ...	1,230	232 × 36·5 × 22·5	10·3	29	5·42 = 5 5
„ 3.	Iron screw steamer, first class	740	249·9 × 30 × 17	14·7	26	3·20 = 3 2
„ 4.	Iron screw steamer, first class	1,554	300 × 35 × 22	13·6	29	5·37 = 5 4
„ 5.	Iron screw steamer, first class	2,048	360 × 37·5 × 22·6	15·9	33	6·27 = 6 3
	Upper deck tonnage ...	730	Upper deck 7·4			
„ 6.	No. 5 as a three-decked vessel	2,778	30·0	12·0	29	7·45 = 7 5½

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EXAMPLE No. 1.

```
 165 length of vessel to nearest foot.
 22·2 = 27·8 − 5·6 = breadth of vessel, less one-fifth.
 ----
  330
 330
330
-----
3663·0) 510·0 tonnage (·139 of a foot equal to 1 per cent. of buoyancy.
        3663          26 Table number
        ----         ----
        1437          734
        1099         278
        ----         ----
         338         3·514 = 3 feet 6 inches freeboard.
         330
         ----
         . . 8
```

EXAMPLE No. 2.

```
 232
 29·2 = 36·5 − 7·3
 ----
  464
2088
464
-----
6774·4 ) 1230·0 (    ·185
         6774        29·3
         ----        ----
         5526         555
         5419        1665
         ----        370
          107        -----
                     5·4205 = 5 feet 5 inches.
```

EXAMPLE No. 3.

```
 250
  24 = 30 − 6
 ----
1000
500
----
6000 ) 740
       ----
       ·123
        ·26
       ----
        738
       246
       ----
       3·198 = 3 ft. 2 in.
```

EXAMPLE No. 4.

```
 300
  28 = 35 − 7
 ----
8400 ) 1554 (   185
         84      29
        ----    ----
        714    1665
        672    370
        ----   ----
         42    5·365 = 5 ft. 4 in.
```

EXAMPLE No. 5.

```
 360
  30 = 37·5 − 7·5
 ----
10,800 ) 2048 ( ·19
         108    33
         ----   ----
         968    57
                57
                ----
                6·27 = 6 ft. 3 in.
```

EXAMPLE No. 6.

```
 360
  30 = 37·5 − 7·5
 ----
10,800 ) 2778 ( ·257
         216     29
         ----   ----
          618   2313
          540   514
          ----  ----
           78   7·453 = 7 ft. 5½ in.
```

The allowances adopted in the following examples are to be supposed as sanctioned by experts. Let the first example be No. 1, as above, with the addition of a long half poop, containing 46 register tons, and of such strength that every 2 tons in the poop are considered to be equal to 1 ton under the main deck. It will thus have 23 tons to be allowed for. Now, Example No. 1 shows that each foot of freeboard is represented by 37 tons (*i.e.*, $\frac{3,663}{100}$); consequently, $\frac{23}{37} = \cdot 62$ parts of a foot and this divided by ·139 gives the equivalent as 4 per cent. of spare buoyancy. So that, instead of 26, as per Table, the per-centage number will be 26—4, or 22. Instead of changing the per-centage number in this way, it may be preferred to retain the Table number, and to move up the marks and figures on the ship's side by ·62 parts of a foot.

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Again, take Example No. 5 as a spar-decked ship, every 10 tons under the spar-deck being considered as equal to 4 tons under the main deck. Then, $730 \times \cdot 4 = 292$ tons for which allowance is to be made; and $\frac{10,800}{100} = 108$, the number of register tons to each foot of spare buoyancy. Then, $\frac{292}{108} = 2 \cdot 7$ feet, and $\frac{2 \cdot 7}{\cdot 19} = 14$ per cent. of buoyancy. Therefore, instead of 29, as per Table, for a flush-deck ship, we obtain $29 - 14 = 15$, as indicating the per-centage mark for "fairly laden" in No. 5, as a spar-decked vessel. Or, as in the previous case, it may be preferred to move the Table figures a space of 2·7 feet further up the ship's side.

An incidental advantage in the use of these per-centage marks is the fact that two of these marks correctly indicate the difference between the freeboard of a loaded vessel in fresh and in salt water.

We now approach a part of the subject which has been much discussed, and is yet, I fear, very much misunderstood. What is a fair and proper load line? This topic is quite distinct from that which we have hitherto considered. What is meant by a "compulsory load line," and what is meant by a "hard-and-fast" load line? The former term only applies, correctly and completely, to a line beyond which an owner should not, under any circumstances, however urgent or proper, be allowed to load his ship. The latter term only properly applies to one which would mark all vessels alike, irrespective of form, strength, proportion, cargo, season, or employment. Both these are, I think, very properly objected to, and by none more strongly than by Members of this Institution. I sympathised very much with our Right Honorable President when, last year, he seemed so reluctantly to give up a load line which he felt would tend to prevent loss of life at sea. If there exists a general feeling in favour of fixing a fair and reasonable load line for all sea-going vessels, I am of opinion that such a line may be found, and that to it neither the terms "compulsory" or "hard and fast" need be applied.

Such a line I propose to find by the use of the preceding Table, or by some improvement upon it, if it is unable to stand the fair criticism which I have freely applied to other proposals.

There never has been much difficulty in fixing a fair load-draught for first-class vessels, of medium proportions, for average weather, and with suitable cargoes. The disputes have arisen as to the deviations from it which would apply to finer and to fuller vessels, to second and third-class vessels, and to vessels of no class, under the same circumstances.

The scheme I propose is founded on classification by Lloyd's, by the Liverpool

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Registry, or by the Board of Trade, and marking on the sides of ships a scale showing per-centages of registered tonnage under deck. The selection of the per-centage marks which indicate a fair load-draught and a "too deep" load-draught is also proposed, but it is not intended that this shall preclude a shipowner from sending his ship to sea loaded to any depth he may think proper.

In fixing a "too deep" draught for legal purposes, this mode of marking a ship is specially important, as it allows different kinds and sizes of ships to be easily and fairly dealt with on the same general principle. The utility, not to say the necessity, for a mark of this kind may be illustrated in this way. A vessel very deeply laden, in the opinion of her crew and of many disinterested persons, sails and soon returns to port again, and there is a rumour that she is leaky. The crew say that she is unseaworthy, and refuse to proceed. The underwriters find that, for an ordinary premium, they have taken a more than ordinary risk. The magistrate, before whom the crew is taken, is assured by the captain that the vessel makes no unusual quantity of water, and has sailed more deeply laden on former occasions; several other captains support their comrade by saying that in their opinion the vessel is not too deep. The crew have the option to return to the vessel or go to prison for a month. The crew feel that they have not had justice, and the underwriters mentally determine not to insure the vessel again unless she is loaded under the inspection and to the satisfaction of their surveyors. Take another case. It is getting to the end of the season, and the last steamers are about to sail for the Baltic. Shippers are anxious to get their goods forward, and the steam shipowners find that they must either disoblige their friends or load their steamers much more deeply than usual. The owners know that the risk will be greater, and that the vessels will take two or three days longer on the voyage; but they will get more freight, they are also their own underwriters to a large extent, and they determine to run the risk. But what of the other underwriters on the ship and cargo, and what of the crew? Are they consenting parties? Are not the former entitled to more premium? Are not the latter entitled to more pay, or to be allowed to leave the vessel without the unpleasant alternative of a month in prison?

The remedy offered will still allow the shipowner to load as deeply as the exigencies of his business may require, only it makes him subject to a special engagement with his crew when his vessel is loaded beyond certain well-defined limits. It relieves the magistrate from the need of weighing conflicting technical evidence, when questions of overloading are before him. It relieves the Board of Trade from the consideration of all questions of unseaworthiness which depend on load-draught, and relieves them also of their present doubts whether, in fairness, they ought not to have prevented certain vessels from sailing.

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The limits of load-draught for this purpose can be easily and systematically defined, if the Legislature will decide:—(1.) That all vessels shall be marked so as to show per-centages of buoyancy, in terms of registered tonnage. (2.) That a certain per-centage mark, selected by recognised authorities, be taken as a fair load-draught. (3.) That vessels showing 5 per cent. of registered tonnage less buoyancy than this, shall for technical or legal purposes, be deemed "too deeply laden."

Fig. 1.—Representation of part of the side of a vessel with per-centage marks, and showing 4 feet 6 inches of freeboard when fairly laden, and 3 feet 8 inches of freeboard when too deeply laden.

Fig. 2.—Part of the side of a small vessel, showing 24 inches of freeboard when fairly laden, and 18 inches of freeboard when too deeply laden.

Fig. 3.—Representation of part of the side of a vessel with per-centage marks, and showing 4 feet 6 inches of freeboard when fairly laden, and 3 feet 8 inches of freeboard when too deeply laden.

Fig. 4.—Part of the side of a small vessel, showing 24 inches of freeboard when fairly laden, and 18 inches when too deeply laden.

Lloyd's and the Liverpool Registries of Shipping have full particulars of all the vessels which they class, and are thus in a position to fix upon a fair and reasonable per-centage of buoyancy for these vessels, if requested by owners to do so. If the owners

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decline or neglect to do this, the officers of the Board of Trade should, after careful examination of the construction and strength of the vessels, indicate on the ship's side, on the ship's register, and in their printed *Register of British Vessels*, the per-centage mark which they might consider to show a fair and reasonable amount of spare buoyancy.

It may be asked:—Why indicate a fair and reasonable per-centage of buoyancy, and then another point, 5 per cent. from it, for a "too deep" line? Some reasons for this have already been given; a further reason is the facility it affords for correct description and for calling things by their right names. In the large seaports it is a matter of common remark, that while certain owners load their ships fairly, there are others who as regularly load them very deeply—possibly, at times, too deeply. To define accurately how a vessel is loaded, I would give a name to each of the five per-centage marks next above that which represents "fairly laden." These names would be, successively, "fully laden," "very fully laden," "deeply laden," "very deeply laden," "too deeply laden;" these terms are already in use, and well understood by the parties concerned.

My scheme, if reduced to its most simple form, proposes to place on the sides of each ship a mark showing, vertically, a fraction of freeboard representing 5 per cent. of the vessel's registered tonnage under deck. The bottom of the mark to indicate "fairly "laden," the top of the mark to indicate "too deeply laden." The exact size and position of the mark is to be determined by experts, acting under an acknowledged public registry or under the Board of Trade (*see* Figs. 3 and 4). In addition to the mark, it will be convenient to indicate from 1 to 5 per cent. of buoyancy above it, and from 1 to 5 per cent. below it, so as to show how much a vessel has been laden beyond "too deep," when this mark is immersed in the water, and to enable one to say, when the vessel is getting nearly down to her load line, how many tons of weight it will take to put her down to the particular per-centage mark which may have been determined upon. This addition to the simple mark will also be of service in ascertaining the exact immersion of the vessel when she has a list.

The kind of mark illustrated by Figs. 3 and 4 will probably be preferred to that shown in Figs. 1 and 2, but these will have assisted to explain what the more simple marks really represent.

About ten different sizes of these marks would suit all sizes of sea-going vessels, if we except only the steamer *Great Eastern*. The sizes of the circular disc would vary from 5 to 15 inches in diameter, by intervals of one-tenth of a foot. They might be strongly made of sheet-iron, with white enamel surfaces, of these regular sizes, at probably less

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cost than that of measuring off and painting them on a ship's side; and thus the work of the surveyors or officers appointed for this duty would simply be to say which of the sizes would be the proper one for each ship, and to indicate the spot on the ship's side where it should be fixed.

It must not be supposed, that because the discs varied in diameter by one-tenth of a foot, that in some cases this would occasion one-tenth of a foot of error in the freeboard of the vessel, as the greatest error from this cause would not be more than one-fortieth of a foot; and this small error, it will be admitted, is of no practical importance. For example, the mark, in any case, would not differ by more than one-twentieth of a foot from the exact size proper to the vessel; and, if the middle of the disc was correctly placed, the top or bottom will evidently be only one-fortieth of a foot out of position.

Such a scheme for a load line as now proposed, though not compulsory, would do much towards forming and educating public opinion on this subject; and to public opinion we all alike bow. It would also be a great assistance to the shipmaster, when sent—it may be to a foreign port—to take command of a vessel which, perhaps, he had never before seen, and of a strength or peculiarity of construction which he had no means of properly estimating. It would assist him also, when pressed by an owner or agent to load beyond what he thought a proper limit, by the remark that other captains had made no objection, and that other owners were earning more freight from a vessel of the same size. The indirect advantages arising from the formation of this public opinion on proper loading, and the influence it would have on the safety of life and property at sea, would no doubt be very great.

In conclusion, I would not have it supposed, for a moment, that I object to the deep loading of a vessel, if all the circumstances are favourable and she is strong enough to bear it. I would only stop at "too deep" loading; for there seem to me few fairer sights than that of a large vessel coming into port, after a long voyage, fully laden with the riches of our commerce. To lightly load a strong vessel, when there are the means of fully loading her, is really a waste of the commonwealth.*

* I take this opportunity to correct a statement inadvertently made at p. 135 of the last annual volume, respecting the scale of freeboard proposed by Mr. R. Duncan. I had not observed that in changing the depth of the vessel in the example from 17·4 feet to 29·5 feet that she would become a three-decked vessel and be governed by a different scale. The freeboard of 4 feet 7 inches would in this way be increased to 6 feet 2 inches.—W. W. R.

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DISCUSSION.

Mr. Benjamin Martell: As Mr. Rundell has been good enough to criticise the Paper I had the honour of reading at our last Meetings, perhaps I may be excused for rising thus early to make a few remarks. All will agree that the subject is very important indeed, particularly when the announcement is made by the Author that the scheme embodied in the Paper just read will in all probability be incorporated in the "Merchant Shipping Act" now before the country. Now let us consider what this scheme of Mr. Rundell's is. He proposes not only to mark a scale of feet on the side of all ships indicating their freeboard, but also, in addition to that, to mark a scale of buoyancy or displacement alongside of this scale of feet. This latter scale is to be marked from zero fixed at some undefined point, downwards to below the load line. I think, if such a scale of surplus buoyancy is to be marked on the side of a ship, under Government compulsion, its accuracy should be beyond question; it should represent what is really correct, something definite, and what one can say truly marks the per-centage of the actual buoyancy or displacement of the ship. I think I shall be prepared to show that what Mr. Rundell proposes would not represent the surplus buoyancy of the ship—that it would be often fallacious, something merely conventional, but in no sense would it show the surplus buoyancy of every vessel. I quite agree with marking a scale of feet on the side of a ship, as recommended by the Royal Commission and embodied in the Government Bill, because I believe any means that can be adopted to show what the freeboard is, without the trouble of measuring, would be very useful indeed; but even here the zero point presents difficulties. Mr. Rundell says his calculation of the tonnage and capacity of the ship corresponds with a certain proportion of the depth of hold—that is, 30 per cent. of capacity corresponds with 3 inches per foot depth of hold, and 25 per cent. corresponds with 2½ inches per foot depth of hold. The natural inference from this appears to me to be that the scale of feet alone is as good as the two scales the Author proposes. If they really correspond so nearly, which I do not admit, what object is there in marking the scale of surplus buoyancy in addition to the scale of feet. Still if it is marked let us insure that it records a fact, that it is something definite, like the *fact* recorded by the scale of feet and inches. The difficulties arising from marking this per-centage scale of displacement on a ship commence from the moment when you come to consider that the upper deck or platform of the ship is not a perfect horizontal plane. To begin with, there is a certain proportion of surplus buoyancy above the height of deck amidships, and the true zero point varies with each change of trim, and how is this to be marked or taken account of? The sheer and round of deck are important elements in the seaworthiness of the ship. We often see little vessels coming up this river—vessels similar in form to the Dutch galliots—loaded down almost to the gunwale amidships, but yet with sufficient surplus buoyancy at the ends to enable them to perform their voyage in safety. Then, again, of still more importance and difficulty is the large number of erections above the upper deck, and the surplus buoyancy of which is to be measured. Mr. Rundell gives an instance of a spar-deck ship—a ship built with the same scantling up to the main deck, and above that the scantlings somewhat lighter, making a continuous deck 6 or 7 feet high, with substantial scantlings, although not quite so strong as in the main body of the ship. How does Mr. Rundell propose to grapple with such a case as this? He says that he would take a certain proportion of the buoyancy or the tonnage due to the space between the main and the spar deck, and call it spare buoyancy. How can you with any show of reason take as Mr. Rundell suggests, 10 tons of the tonnage

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between the main deck and the spar deck, and call it for purposes of spare buoyancy equal to 4 tons of tonnage below the main deck? Such a process can surely have nothing to do with spare buoyancy. It would be a misleading and absurd pretence to call a scale so formed a scale of surplus buoyancy. Just imagine a person going into a court of law with a ship marked in this way, to be examined as an expert, and called upon to say what amount of surplus buoyancy a certain ship had. He would perhaps say 25 or 30 per cent. of surplus buoyancy. Then suppose he was asked, "Do you mean by surplus buoyancy a certain "per-centage of the whole buoyancy?" the answer would have to be, "No, not that." "Well, what is it?" "Why 10 tons of tonnage above the deck, in this particular vessel, I consider equal in buoyancy to "4 tons of tonnage below the deck, although in reality it is either *strong* enough to remain water-tight "and afford its full 10 tons of buoyancy, or if it is not it has no buoyancy." This is sufficient to show the absurdity of the thing. It pretends to govern the freeboard by buoyancy, and really all turns on a question of *strength*. In my opinion it is, moreover, not at all a practical scheme. I would appeal to any professional man whether he would undertake to mark upon a steamer whose deck is covered with erections of different degrees of strength, the actual scale of true surplus buoyancy, and say it should regulate the freeboard? The difficulty applies in the same way not only to a spar-deck ship, but to a long poop or raised quarter-deck ship, and in fact to nearly all steamers. Either the state of the superstructure is sufficiently strong to allow of its affording surplus buoyancy—it either forms a portion of the ship, and really is utilised as surplus buoyancy, or if it is not strong enough, and does not keep the water out, it is of no use for surplus buoyancy, and therefore it is a misnomer to call it surplus buoyancy. I do not dispute that in such ships, with substantial erections there should be an allowance made in fixing the load line—make an allowance by all means; but to call it by a name that has no truth in it, and for the Government to compel this untruth to be marked on every ship's side is surely out of the question. That is my great objection to a buoyancy scale being marked upon the side of each ship. I should be exceedingly sorry to see the Government of this country adopt such a scheme as this, because, in my opinion, it would bring the law into ridicule and lead to no end of difficulties. I was talking a short time ago to one of our great shipowners, and he told me that he had taken the scheme and read it carefully, but that he did not understand what the meaning of it was. So much for the simplicity of this scheme of Mr. Rundell's. Now, with reference to the objection he has raised to the Paper I had the honour of reading before this Institution last Session, it is evident to me that Mr. Rundell has quite misunderstood the matter, and has fallen into grave error. He complains very much that certain modifications were made in the Paper I read here, as compared with the Table placed by me before the Royal Commission. I admit that there were modifications made—modifications to suit the increased knowledge and greater experience which I had gained, and it is such an immense question, and so much knowledge can be gained upon it, that if I am spared until next year, and have the honour of appearing here and reading a Paper on the same subject, I have no doubt that I shall have still more modifications to make. I think anybody who has endeavoured to grapple with this great question of the load line must see that it is continually open to improvements—there is no such thing as finality about it. Mr. Rundell says if he only knew the novelty of the manner in which the per-centage of buoyancy was calculated in my Tables he would be able to get at the mystery of them. The fact is, there is no mystery about them. To naval architects it will be unnecessary to explain how per-centages of buoyancy are arrived at, but still I will briefly explain our manner of setting about it. We obtained throughout the country a very large number of drawings from shipowners and shipbuilders, and calculated the actual displacement of these

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ships, and from that we ascertained what amount of buoyancy there was above the load line given by the owners and builders; and from that any one understanding such calculations could easily understand that by taking the tons per inch immersion we could get at the average per-centages and corresponding freeboard as put into the Tables—24, or 25, or 30 per cent., whatever it might be—so that the per-centages are cut off—I do not say with exactitude, but sufficiently so for practical purposes. We might have taken, as Mr. Rundell has done, a simple co-efficient, and multiplied the registered tonnage by it, to obtain the displacement, but we went further than that, and devoted six months and a great deal longer than that to actual calculation to produce the results. Again he says the Tables cannot be correct, because the co-efficients do not vary in the same proportion as the freeboard, or the freeboard does not vary in the same proportion as the co-efficients. That is an error into which it was easy to fall. He assumes that the vertical sections of all these ships are the same above water, which is by no means so. If we had taken merely the co-efficient, as he does, of displacement or tonnage, and multiplied that to ascertain the displacement, we could have got a perfectly uniform Table no doubt; but we did not do that, we made the necessary calculations, and regulated these per-centages by the varying types of ships actually in existence. I should have been glad to have had a little more time to enter into further explanations, but his Lordship has intimated to me that the time allowed me has expired. I can only say, in conclusion, that I should be very sorry indeed to see such a scheme as Mr. Rundell has proposed become law; namely, to put per-centage marks on the sides of all ships, because I am certain, as I have said before, that it would be fallacious and misleading. I think it would be desirable to mark on all ships an average load line for reference. This was advocated by me here on the last occasion, and was also laid before the Royal Commission. I think if such a load line were fixed it would be unnecessary to mark scales of buoyancy or anything beyond a simple scale of feet and inches.

Mr. Charles M. Norwood, M.P.: I think a moral may be drawn from the Paper we have just heard read, and from the observations which have been addressed to us by Mr. Martell. Mr. Rundell is a gentleman who has bestowed an immense amount of attention on this question of scientific freeboard. He is connected with the Liverpool Registry, and Mr. Martell, on the other hand, is Chief Surveyor of Lloyd's Register of Shipping, and an authority of the highest class, and yet both those gentlemen express at this present day the difficulty they have in agreeing on what would be the proper principle to be adopted for fixing the exact load line. Now, the moral I draw from that is, that it is somewhat premature to attempt to force by Act of Parliament an authoritative load line on the British shipowner. I do not say that I object to some indication of a load line on a ship. I think there are reasons why such an indication would be an advantage, and I have determined to submit a scheme to the House of Commons which, I think, at any rate, may prove a satisfactory temporary expedient. I propose that in addition to the scale of freeboard amidships, which the Government Bill provides, to compel a shipowner, on or before the 1st of January next, to fix his own maximum load line. It must be painted, and must be indelible; the description of it must be placed on the ship's register, on the articles of agreement with the crew, and the official log. Now, a shipowner is not altogether a man devoid of some power of judgment; he is a much-abused animal, but still, like everything else in this world, he is not so bad as he is painted; and I think the practical experience that every intelligent shipowner attains as to the quality and capacity of his ship, the information which he has a right to expect from the builder of his ship, and can obtain by applying to gentlemen like Mr. Martell and Mr. Rundell, will enable him to come to something like a reasonable

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conclusion as to the maximum line he should fix on the ship. I think it does not necessarily follow that a shipowner would fix a very improper line, and that the amount of surplus buoyancy he would indicate would be much too little; because you must recollect, in the first place, that every shipowner is subject to the competition of his fellow shipowners; that he is closely watched by the surveyors of the various bodies of underwriters, and those expert gentlemen would be able to form an impression as the amount of judgment and fairness which the shipowner has exercised in fixing this voluntary load line, if I may say so, upon his ship. Then we have the principle of competition—one shipowner competing with another in every trade—and if a merchant or an underwriter finds that there are two ships offering for freight at the same time, no doubt the preference would be given to the shipowner who gave the most liberal and the most satisfactory amount of surplus buoyancy, by this line which I propose he should mark on his ship. But the principal advantage I see is this, that it will enable us to commence an experiment with reference to placing a load line on the ships, and to avoid the objection which does exist in many quarters, and notably in the Board of Trade, as to the responsibility which they may incur by recognising an authoritative load line. I believe that everybody knows that the determination of the Board of Trade is not to incur the responsibility of an official recognition of the load line on the present occasion, because the Board of Trade says, "We should then and there step in and absolve "practically the shipowner from that supervision and management of his own affairs which we consider to "be an essential principle." Now my proposal is that this load line should not only be marked, but marked in paint very clearly, and that there should be a severe fine inflicted for its obliteration and removal; and not only that, but, as I said before, I would have it placed on the ship's register. That would be notice to all the world. The merchant can have proof of it. He can have ocular demonstration if he chooses to send his agent down to the docks, because he can see the line marked, or he can go to the Custom House and refer to the ship's register, and can see the proper description of the line. The underwriter can do the same thing, and above all the sailor is protected by it. In my view all these discussions of ours should really have for their primary object the protection of the sailor; because, my Lord, I may tell you, what you yourself will acknowledge, that shipowners, and underwriters, and merchants can take good care of their own interest; but, in a national point of view, the great object we have is to endeavour if possible, to secure the safety of our sailors. If a sailor has the power of seeing with his own eyes the maximum depth to which an owner claims the right to load a ship, he has notice of what he may expect. He has that statement in his articles, so that there can be no possibility of the shipowner defrauding him by making an alteration as to the exact mark which he has adopted; because I intend putting a clause to this effect, that when this load line is not visible in sea water, or any portion of it, that that *ipso facto* relieves the sailor of his engagement under the ship's articles. I would not allow a shipowner to be able to arrest or punish any sailor for either absenting himself from his ship, or refusing to join it, if the safety line which the owner fixes is not to some extent visible in salt water. My Lord, I trust you will not find fault with me for addressing these few remarks on this occasion, because I came here to gain that scientific information which is afforded by scientific men; and seeing, as I have pointed out in the commencement of my remarks, how extremely difficult, and how extremely intricate the subject is—the two greatest authorities in the world differing so widely—I ventured to think possibly that some public good may arise if the shipowner himself, at any rate in the first instance, was called upon to indicate to the public what he himself deemed to be the maximum line. We do not thereby absolve any shipowner from the duty and the task of managing his own affairs and from providing for the reasonable safety of the life

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and property in his charge. It is a line that need not be used in every case. Certainly in some cases a shipowner would not dare to load his ship to the mere maximum line, which would be in other respects a danger line. Sometimes in fine weather, under very auspicious circumstances, he would do so, and under very exceptional circumstances indeed he might even exceed it; but if anything happened to the ship he might have to answer for it in a court of justice. I fancy that the underwriter would have a good reason for disputing the seaworthiness of the ship if he could prove before a judge and jury that the mark which the owner voluntarily put on the ship as the maximum load line, had been exceeded. It would be then the duty of the owner to prove that there were certain exceptional circumstances which justified him in so doing. At any rate I shall endeavour to make a contribution towards the solution of the difficulty which we are at present in, with regard to legislation as to merchant shipping, by the proposal which I have laid before you. I think, so soon as the Council of this scientific body are perfectly satisfied that they have arrived at the solution of the question, that then will be the time for shipowners to consider it; but I do think, in the meantime, there is something of a practical, and fair, and reasonable nature in the proposal which I intend to submit, and I think it will give that proper and sufficient and due notice, both to the merchant, the underwriter, and especially to the sailor, which those three classes of men have a right to expect from the shipowner.

Mr. John Scott Russell, F.R.S.: I am sure we must all feel extremely grateful to Mr. Norwood, who is well known as one of the most careful, trustworthy and responsible shipowners, for the remarks he has made. I have only to express my sorrow that he was not here during the whole of the Discussion, and during the reading of the Paper, otherwise he would have seen that we took much more the side of shipowners than he has taken. I beg to say to him in return to a challenge which, I gathered, was contained in one of his sentences, that we are more in favour of the shipowner than he is, and that the verdict we have passed by the precautions we had arranged to take before he came here, is much more in his favour than those he wants us to take. He wants us to lay on the shipowner, who is not the shipbuilder, the responsibility of saying what the proportion of the capacity of the ship shall be above the load water-line and below the load water-line. I do not think I know one, but certainly I do not know two, shipowners in the world who could give an absolutely logical explanation of what was the principle on which they have drawn this particular line. Now, before Mr. Norwood came here, we had almost unanimously agreed, I think, that we would not impose on the shipowner any hard-and-fast line whatever, but that we would endeavour by all the means in our power to communicate to the shipowner, and the shiplader, and the public, as much information as possible as to what the actual state of the ship was at the time. There are three people who could fix a load line, perhaps there are more; we will see. First, there is the shipbuilder: he might say for what load line he had constructed his ship—that might be marked on the ship. That is the first case. The second case is this: that the surveyors of the ship, either Lloyd's surveyors or the Custom House surveyors, might register on the ship a line which said how much of the ship was left out of the water, and how much of the ship was sunk under the water; and then we might have the third kind of load line which has been suggested in this particular Paper. Now I think the general impression of this Meeting was that none of these should be a line by which the shipowner should be in any way bound—that it should be a line of record for the purpose of giving information, but that then the shipowner should judge, with regard to the particular voyage his ship was going upon, on his own responsibility, whether he chose to load his ship below that line or above that line. Thus, we

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left the information quite precise, the marking of the ship quite precise, and the liberty of the shipowner much greater than that which Mr. Norwood's system would leave to him.

Mr. CHARLES LAMPORT: Mr. Scott Russell has said nearly everything which I should have been inclined to say with reference to this matter, but there is one point which he has still left untouched. I think all the speakers have been speaking too much of ships, and the idea attached to a ship is rather a structure propelled by sails than a steamer. Now, with regard to a steamer there is this great difference, that the weight and bulk of her cargo is every day varying. When she goes to sea she carries a full cargo of coal for her consumption, and in many cases enough for her return voyage. Some of the large steamers burn from 60 to 80 tons per day, and after she has been one day at sea that militates against the justice and propriety of her load line, whatever it is—be it Mr. Rundell's, Mr. Martell's, or, as Mr. Norwood suggests, the shipowner's own—she is putting in a protest, as it were, against that hard-and-fast line every day she goes to sea. I should like to ask the question why, when another doctor has got up to disagree with the doctors who prescribed before, we do not turn them all out of the house, and resort to the sound, judicial, and temperate judgment which the Royal Commission has formed in reference to doing what Mr. Scott Russell has so well stated—getting up a record of information in regard to the state of the ship, so that if at any time anything happens to her there is evidence wherewith to go into a court of law, and punish the peccant shipowner, and mulct him in damages. I think myself that is the only fair and proper principle to go upon. Let there be, as the Royal Commission states, in the first instance, all the information possible got with respect to the ship; let there be marks put on so that anybody looking at her as she goes to sea may see what water she is drawing; and let that, as the log would accord it, be evidence of the amount of freeboard. When that ship is lost, if unfortunately it should so happen, a court of inquiry is then provided for by the Bill, and very properly; and that court of inquiry will make out whether or not that ship was seaworthy—and make it out, as it appears to me, by the only trustworthy evidence that can be brought forward. When interested parties on both sides come to discuss the question, then the jury will decide whether or not the ship was seaworthy; and the jury will have the means of doing so when what Mr. Scott Russell has proposed, and the recommendation of the Commission, embodied in the Bill before Parliament, be made law, and when a record of information shall have been prepared beforehand. Now there is a process in law, and a simple and efficacious matter it is in commerce, which goes under the name of "liquidated and assessed damages." It means that if anything happens so that a contract is broken there shall be no necessity to ascertain how much the damage is, but a statement in the contract puts forward the amount, and it can be enforced. Let such a statement be made in the charter party on the one hand, and also in the engagement note of the seamen; let such liquidated and assessed damages be stated, and if there be an inquiry, and the ship is proved to be unseaworthy from information recorded, it seems to me a simple thing that the shipowner should be punished to the utmost extent to which he may be held liable. As to there being any hard-and-fast line I am perfectly satisfied myself as an underwriter, and as a shipowner, that it is a thing which would fall to the ground, as the Commission states has been the case with six or seven previous measures of the same sort, measures which have fallen into desuetude—which could not be applied—which were opposed to public opinion—which would not work, and had therefore to be repealed.

Admiral the Right Hon. the EARL OF LAUDERDALE, K.C.B.: As to this question of freeboard there appears to be a general opinion in this Institution that it should be entirely decided by the

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shipowners. Now, I beg to state that there is another party who ought to have something to say on the question—I mean the officers and men, the persons whose lives are at stake, and who are the best judges in my opinion of what is an efficient sea-going ship, because they are the only men who go to sea and try it. I said a short time ago that the bottom of the mischief was the insurance, but that is a very difficult point to deal with. Is it to be left to shipowners who are deeply interested in having the ship deeply laden? We heard just now what a comfort and pleasure it was to a shipowner to see a beautiful and deeply-laden ship arrive safe in port. I would merely say that he is a lucky fellow to see her come in at all. The seaman and the shipbuilder, in my opinion, will never agree as to the height of freeboard—I do not think they ever will. The freeboard given in those Tables—and we have been two years discussing this—is not sufficient for a loaded and particularly long sea-going ship. I will take a ship in the Navy, say the *Monarch*. The *Monarch* is 12 feet out of the water. The *Monarch* has also got a forecastle on her. From my experience at sea, I believe that if you were to cut the forecastle off the *Monarch*, and leave her deck flush fore and aft, if she was steaming against a sea, no man could live on her decks. The difference of putting that 4 or 5 feet higher saves the deck from being washed, and therefore it is absolutely necessary, particularly as we are building these very long ships of 10 and 12 lengths, that you should increase the freeboard, because a small ship, as we all know, rises to every sea—a vessel up to 500 tons—a 150 tons cutter never takes the sea over the decks. It rises to everything, but these long vessels do not rise, they take the sea clean over them, and you must consider that very carefully in fixing your freeboard.

Mr. J. Scott Russell: The poop and forecastle is quite another question, but a very important one.

Mr. W. W. Rundell: I would first thank the Secretary for his kindness in reading the Paper, and, in the next place, I would wish to remove the misconception which appears to have arisen in the minds of some gentlemen here as to what I said probably would be introduced into the new "Merchant Shipping "Acts Amendment Bill." I said that a scale showing spare buoyancy would probably be inserted in the Bill as well as the scale of feet, but I did not venture to say what scale of freeboard. Certainly, the idea that any scale of freeboard that I had proposed here was to be included in the Bill never entered my conception, and I should be very sorry for such an impression to be promulgated. Then, as regards the spar-deck allowance, I cannot see a material difference between making an allowance in feet or in capacity—for instance, suppose a spar deck 7 or 8 feet high, making an allowance of a fourth of the height of that spar deck, or a fourth of the tonnage contained in that spar deck. It seems to me that the same objections which would apply to the one mode of making the allowance would apply also to the other. It was a mere matter of consistency which made me propose, as I did, that as tonnage governed the freeboard—that the tonnage also of the spar deck should govern any allowance that might be made for the spar deck. Tonnage or feet is really a matter of indifference, because I believe in both cases the allowance would practically be the same for the spar-deck erection. Turning to another point; I should be glad to state that one proposal which has been made here to-day during the Discussion has been tried for some years past or was, some years ago, tried in Glasgow. There it was customary for the broker who intended loading a ship to send round to the underwriting offices a memorandum stating to what depth he intended to load her, stating also how many tons he proposed to place on board, and what proportion of that tonnage was to be of heavy goods and what of light. He did not bind himself strictly to this, but he said that was his intention. He stated on entering his ship outwards, how much cargo he intended to carry,

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and the kind of cargo—that is, how much dead weight and how much light cargo. That was usual some years since and was found to work very satisfactorily. The underwriter knew exactly the risk he was about to take, because he knew, within certain limits, in what way the ship was to be loaded. Very much the same idea has been thrown out here this morning. With regard to the remarks made by the noble Earl, I believe that it will be agreed that the commander of the ship—the man who risks his life on board, the man who has charge of the property and lives of the crew—is really the man who ought to be able to say to what depth the ship should be loaded and the man to whom the whole matter should be left. But practically, this is not now the case and never can be the case. He cannot control the amount of cargo put on board the ship or the disposition of it; he steps down, perhaps, at the last moment, and knows nothing at all about it. He may, perhaps, go on board a ship which he has never seen before, and as to whose strength or construction he knows nothing, and yet he has to navigate that ship, however she may be loaded, and is expected to take her safely. He has no voice in the matter, and I know of no way of giving him the necessary voice.

Mr. J. Scott Russell: Except making him the stevedore.

Mr. W. W. Rundell: And even then he cannot control the way in which the goods shall be brought down to the dock side. The heavy goods may be brought first and the lighter goods afterwards, or it may be the contrary. All that I think can be done—as has been already stated over and over again at this Meeting—is to give information of the most precise kind that you can; one kind of information is given by the feet marks on the side of the ship, and another correlative kind of indication would be given by the per-centage marks for showing spare buoyancy which I have proposed in my Paper. The exact depth to which any ship is loaded must be left entirely, as Mr. Norwood remarked, to the owner; with the understanding that if he loads her beyond a certain mark, his ordinary agreements with his crew and underwriters are at an end, and that he must enter into an entirely new arrangement with them to suit the new circumstances.

The President: I have only to thank Mr. Rundell for the Paper which he has read, and to state that our proceedings will be resumed this evening.

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ON A MODE OF OBTAINING THE OUTLINES OF SEA WAVES IN DEEP WATER.*

By W. W. Rundell, Esq., Secretary to the Underwriters' Registry for Iron Vessels, Associate.

[Read at the Sixteenth Session of the Institution of Naval Architects, March 18th, 1875; the Right Hon. Lord Hampton, G.C.B., D.C.L., President, in the Chair.]

In the list of subjects which our Council proposed last year as suitable for Papers for this Meeting, was included that upon which I now beg to offer you some brief suggestions. To me this topic possesses peculiar interest. There is always a charm in watching the changing and fugitive forms of the waves, their glancing lights and soft shadows; and science adds much to the pleasure derived from their contemplation. The study of their origin, their form, their structure, so to speak, their times of oscillation, their enormous speed and the distances to which they travel, in turn occupy the imagination and task the intellect. To the seaman, in hours of melancholy, they speak a language of their own, fraught with mystic dreams and false songs of syrens.

The accuracy of observation by which the intelligent mariner will distinguish in a "confused sea" the direction of its principal components, and the precision and uniformity of description with which different seamen will describe the particulars of the same gale, have often surprised me, and at the same time occasioned regret that they had not also supplied those details of length and interval which would add so much to the value of their reports.

My present subject relates chiefly to wave forms, and the data which they may afford for obtaining their chief components; and I think photography, aided by the mechanical arrangement which I am about to describe, will supply the means of obtaining these with a considerable degree of accuracy. The assistance which photography has recently rendered to astronomy in recording the position of Venus at successive intervals as she passed across the sun's disc, will readily suggest the mode in

* Received March 17th, 1875.

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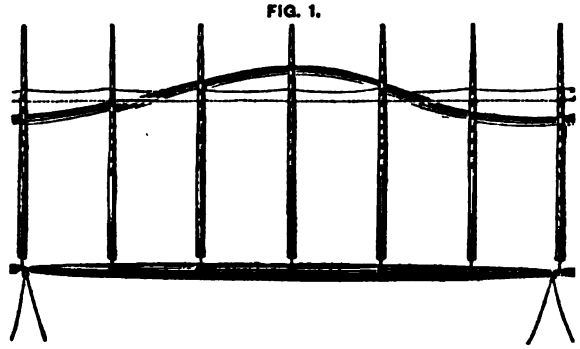
which it is now proposed to use it, while the accompanying sketch will show how those measurements are to be made by which the wave outlines are ultimately to be traced and put into a form suited for mathematical investigation.

In Fig. 1 is represented a number of poles, such as are used by builders in the erection of scaffolding. They are about 36 feet in length, and painted with alternate bands of red and blue, each band being a foot in width. These poles are spaced 15 feet apart, and are loosely coupled at their larger end to yards or spare spars, extending, we will suppose, to a length of about 600 feet. The centre part of the figure represents an ordinary yard of about 90 feet in length. This system of poles is to be prepared in duplicate; the two parts are to cross each other at right angles when in use.

FIG. 1.

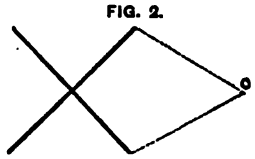


In moderate weather the different parts could be connected while floating on the surface of the water, lengths of wire or small wire-rope being used to keep the upper parts of the poles equidistant and parallel. When the construction is completed, proper weights are to be attached to the ends of each yard, so that as the yards sink and draw the poles with them, the poles will at length remain upright with about 12 feet of their length above water.

I do not intend to trouble you with any details as to the mode of doing this, as I conceive it presents no greater difficulty than the crew of a man-of-war could easily surmount. Such a system, when once set afloat in the open sea, would be likely to remain for some little time without injury.

From the crosstrees of a large vessel situated about 600 feet to 700 feet from the centre pole the whole would subtend an angle of about 60° (*see* Fig. 2), and a wave slope of 10° would be commanded at the most distant part of the system. The photographs would have to be taken from this elevated position, but it is not requisite that they should be taken from the same point of view; the movement of the vessel during the 20 or 30 seconds, or more, during which the experiment would be made, would not affect the result, the only essential being that the pictures should be taken at short and regular intervals.

FIG. 2.



It may be objected that this proposal involves a good deal of uncertainty; that when the system of poles is successfully set afloat, some time may elapse before the chance of photographing large waves would occur; and that at the time when the waves possessed

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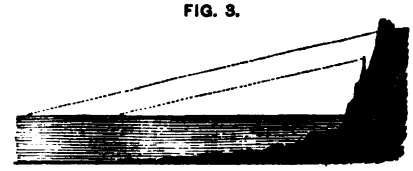
most interest, the position of the photographer in the crosstrees of a man-of-war would not be a pleasant one, and that there would be great difficulty in presenting the camera in the proper direction, and in taking the pictures at the proper intervals of time.

I admit the force of these objections, and that only under favourable circumstances of wind and weather would the attempt succeed; I therefore look round for some more stable platform for the operators, one situated at some distance from the mainland, and where unbroken Atlantic waves of large size may be found. The Fastnet, Skellig, and Tearight Lighthouses present themselves, all some distance out in the open sea, and respectively of 148 feet, 175 feet, and 275 feet height above the sea level. A little inquiry shows that of these the Skellig is in the most desirable position, it being near deeper water and a smoother sea bottom than the others. Further inquiry shows that here also is an old lighthouse not now in use, with a lantern 372 feet above the sea level; and, if still greater elevation be desired, there are rocks near it which rise to a height of 600 feet to 700 feet. Here, then, we apparently find a most suitable position, if our system of poles can only be securely moored in about 40 to 50 fathoms of water, from a quarter to half a mile distant from the rock. From the somewhat level platform of the islet, but below its highest pinnacles, a wave slope of 15° could be commanded at a distance of more than a quarter of a mile. *See* Fig. 3, as giving the proportionate heights of old lighthouse, rock, distance and depth of sea.

FIG. 3.



The following is the account given of the Skelligs in the Admiralty Sailing Directions for the S.W. of Ireland:—

" The Skelligs, consisting of two pinnacled rocky islets, surrounded by deep water, " and free from outlying dangers, stand conspicuously out from this part of the coast. " The outer rock, called Great Skellig, three-quarters of a mile long, one-third of a mile " wide, and 714 feet high, with two lighthouses on its western side, lies W. by S. " 6½ miles from Puffin Island, and is only accessible at those spots where steps have " been hewn for the convenience of communicating with the light-keepers. Blindman's " Cove, on the east side of the rock, is the best for this purpose: a well-constructed " road, defended by a wall of masonry, is carried from it along the south side of " the rock to the lighthouses.

" On the high eastern part of the rock there are the remains of a monastic establish- " ment of the early Christian ages, consisting of a walled enclosure, solid and unbroken " after the lapse of so many centuries, though built of dry masonry. Adjacent to it is a " small square building of similar structure, said to have been the church, where the

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"inhabitants now assemble on Sundays for their devotions, and close by a well, "perennially filled with water. The highest peak, called the Needle's Eye, rises from "the north-west part of the rock; on its summit is a breast-work of dry masonry of "the form of a horse-shoe, erected by the monks as a place of prayer. Between the "Needle's Eye and the eastern elevated position of the rock, a deep depression, called "Christ's Valley, presents some sweet herbage, with several ancient graves and rude "crosses.

"A boat from Port Magee communicates twice a week with the light-keepers, "weather permitting; the longest interruption from the weather to this intercourse with "the shore has been five weeks."

The difficulties here do not seem insuperable, and I contemplate in imagination our photographers landed with their apparatus on these forlorn but enormous rocks, and spending a month of summer or autumn in taking occasional pictures of the sea. If our floating system of poles will only remain in view for these few weeks, no doubt many good sets of photographs could be obtained, and perhaps the history of more than one gale be for the first time photographically recorded. First would perhaps come the long heave of a westerly swell, raised by powerful winds which had died out or changed their direction some hours previously—a swell so long and shallow that one might be unconscious of its presence except for the occasional wash at the base of the cliff. The next set of pictures would, perhaps, give us waves from the southward, to be followed a few hours after by a cross sea from the N.W. A few hours more and the local gale will have passed, the chief feature in the last set of photographs being again, perhaps, the remnant of the long western swell which preceded the gale. As illustrating the persistence of wave motion and the distance to which it will travel, I may mention that Captain Toynbee has found a swell from the north-western part of the North Atlantic to not infrequently reach the Azores, where the wind for some time may have been blowing in quite a different direction.

Suppose it were determined to carry out such experiments as I have suggested, and for the term of a month, one or two sets of photographs per day, when the weather suited, would be sufficient to keep the staff in practice. When larger waves occurred a set of pictures every two hours might be taken, or even more frequently than this under specially favourable circumstances.

It should be mentioned that the success of this plan in no way depends on the yards or spars to which the poles are attached remaining in the same horizontal line. They may, and no doubt would, rise and fall to some extent with the larger waves. Datum

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lines would have to be drawn through the tops of the poles on each photographic picture, and from this line would have to be read off the space on each pole which intervened between it and the surface of the water. A practised eye would easily read off these spaces to the nearest tenth of a foot. A few degrees of inclination in the poles would not cause much error, but even this could be eliminated, as the method possesses the elements necessary for correction of this kind. I do not pretend to say to what use a number of such wave outlines could be put when taken, neither do I think this necessary. In the pursuit of science this question has never been considered an important one. But I feel assured that a Froude, a Merrifield, or a Bertin, if in possession of such outlines, would very soon tell us the length, depth, and interval of each component wave, and the direction of its motion. Our Council have asked for suggestions on this subject, and in response I beg to contribute my first, and it may be only my very crude ideas on a very interesting topic.

DISCUSSION.

Mr. W. Froude, F.R.S.: It is always extremely interesting when persons who are engaged in the same object find their way to accomplish it by the same roads. This is a subject which I have had occasion to think about and investigate a great deal, and when I saw Mr. Rundell's diagram this morning I was interested to perceive that he was on a track that I had been working in before, and which my friend Mr. Tower (who is going to read a Paper here to-night) had also independently hit upon. The difficulty which Mr. Rundell mentions of the poles rising and falling is I fear more serious than he has contemplated. I doubt whether the instantaneous photograph of the poles would really fix their *datum* level, because it is very seldom that they would lie ranged in a straight line; and if the line were not straight, the *datum* observed from an elevation, such as a lighthouse, would partake of all the sinuosities of the line, and might introduce considerable error. Any attempt to localise the poles would introduce a great difficulty by reason of the great inclination a pole is driven to when anchored in a tide-way, and one can hardly be sure of being clear of a tide-way. I am merely suggesting the difficulties which *primâ facie* occur to me with reference to Mr. Rundell's method—though it no doubt contains the elements of a complete determination. The method I pursued only aimed at determining the crests and hollows. I used a single pole, and in order to secure the *datum*, I anchored the pole in the undisturbed water at a great depth. The pole was a graduated pole, like Mr. Rundell's; it was held upright by a ballasted platform sunk down to a depth equal to the distance between the wave crests, if the water allowed this without grounding; in that way in the deep water in the Atlantic you could reach still water by lowering the weighted platform to even a greater depth; and that still water would give you virtually a *datum*. Still there was a difficulty in this—that the duration of the very long waves was such, that even with a very large platform, the extra flotation of the pole when deeply immersed involved an element of error. A platform 2 feet or 3 feet square, with a pole 3 or 4 inches in diameter, would produce a sensible

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disturbance in the platform during the transit of the waves. With a larger platform you can get a better effect; but the quantity of line you get out, and the weight you have to employ in ballasting, and the difference in the drift between the surface water and the subjacent water, which becomes a disturbing force on the line of the poles, introduces a great difficulty. With reference to profiles of waves, the difficulty is that you rarely get anything like a regular system of waves, because there are almost always several distinctly visible systems crossing each other, and probably more than one series each way, one overrunning the other, and mixing up in the most inextricable confusion. The only case in which we can find waves so regular and uniform as to be worth reducing to actual diagrams is, I think, when we encounter the result of some gale which has blown a long way off and subsided. Then it happens that the long waves, having a much greater speed than the short waves, outrun them, leaving all traces of the minor disturbance far behind them. Wherever the wind is blowing there are waves of indefinitely varied periods superimposed one on the other; and it is almost impossible to disentangle the larger waves from the smaller ones. That is a difficulty which is inherent in the result aimed at unless you can pitch upon a place where the great rollers come in undisturbed by momentary wind.

Mr. CHARLES W. MERRIFIELD, F.R.S.: I am hardly prepared to offer any observations upon this Paper; but I may mention, with reference to what has just fallen from Mr. Froude, a self-recording apparatus or a pole that was tried by Admiral Paris on a small scale in shallow water, and you will find an account of it in our *Transactions* three or four years back. I cannot give you the reference to it at this moment, because I have not the volume by me; but members of the Institution will have no difficulty in finding it.*

Mr. W. W. RUNDELL: I desire to say that there is a very considerable difference between the use of one pole and the use of the system of poles. Some year or two since I heard Mr. Froude describe the experiment which he had tried of using one pole. I think a little consideration will show that with one pole you do not get the record of any particular wave. To obtain the outline of a single wave, or of a set of waves, you must get measurements of the different parts taken at the same moment. Any system of observing the passage of the water, or the waves, by a single pole does not meet the case at all, for you there get records of heights of water at different intervals, but have no means of ascertaining what part of the measured height belongs to each set or series of waves. In the plan I propose I have tried to avoid this difficulty, and the possibility of it seems to me to depend on the photographer being able to take the impression at a given instant. The sinuosity of the lines in the horizontal plane has really been largely exaggerated; because, supposing the wave slope was a slope at the surface of the wave at 10 degrees, the pole being anchored in deep water would not be normal to this but to the surface of some less inclined stratum of water below. It would be less than 10 degrees—say 7 degrees. Now 7 degrees deviation from the vertical in any direction would really not affect the result. It would cause no inaccuracy of any moment in this matter, because the tenth of a foot, which I put as the degree of fineness with which the scale could be read would cover, as it were, these little inequalities arising from possible deviation from uprightness in the poles. For these small angles the radius and the co-sine would be practically the same. That I think meets, to some extent, the objection Mr. Froude has raised. The idea of the pole is entirely Mr. Froude's own, as I heard him describe it once before. What I would call

* *See* Vol. VIII. for 1867, p. 279.

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his attention to is the use of a series of these poles so as to get an outline of different parts of a compound wave at the same moment. Now, if the waves repeated themselves within certain intervals of space and time, the calculation of the components of each of the waves would be very easy. I could manage that comfortably, although I make no pretensions to mathematics; the difficulty arises when these conditions do not obtain, and hence the necessity for two sets of outlines in planes at right angles to each other measured from rectangular axes. I think that such men as I have alluded to in my Paper would be able by this method to give us fuller and better particulars than we have yet had of the different components of large sea waves.

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ON THE GRAPHIC INTEGRATION ON THE EQUATION OF A SHIP'S ROLLING, INCLUDING THE EFFECT OF RESISTANCE.*

By W. Froude, Esq., F.R.S., Vice-President.

[Read at the Sixteenth Session of the Institution of Naval Architects, 18th March, 1875; the Right Hon. Lord Hampton, G.C.B., D.C.L., President, in the Chair.]

For the sake of brevity, I must assume as sufficiently established what is now generally called the mathematical theory of the rolling of ships.

The chief practical defects of the theory, lie in the fact that, owing to mathematical difficulties, it cannot be fully interpreted except by throwing out of the account certain dynamical conditions of serious importance. By far the most important of these are the elements of resistance which the ship experiences in rolling. The importance of these is witnessed by the circumstance that, but for their operation, every ship of ordinary form would infallibly be overset the first time she encountered co-periodic waves. The theory, indeed, sufficiently proves that this must happen if the ship oscillated without resistance; but it does not show, except in an imperfect and limited manner, what will happen to her in this and other cases including the effects of her resistance.

Another condition which has to be neglected, in applying the theory, lies in the peculiarities of the law of stability involved in specialities of form in ships. I mean those peculiarities which are expressed in what is called the curve of stability. In dealing with low freeboard ships this omission also is of serious importance.

The object of this Paper is to show how the mathematical difficulties may be mastered by employing, instead of a symbolical method, a special method of graphic integration which I have arranged suitably to dynamical problems of this class, and which is capable of bringing correctly into the account any dynamic conditions governed by geometrically expressible laws.

It would occupy too much time were I to describe in detail the commonly employed

* Received 16th March, 1875.

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methods of what is called "graphic integration"—that is to say, the semi-geometrical processes by which the solution of intractable mathematical problems is in many cases effected. As a familiar and slight example, I need only refer to the ordinary method of determining the work of the steam on a piston, by measuring the area of an indicator diagram. All I need say is, that the ordinary methods, so far as I understand them, do not readily lend themselves to the treatment of a problem in which, as in the case we have to consider, the forces which govern the movements of the body, arise afresh at each instant, as the direct and indirect effects of the very movements they are creating. The method I am about to explain is perfectly capable of dealing with this circumstance.

To render the principle of the method clear, it seems best to trace its course in a general or abstract but popular form, before I follow out in a somewhat more technical manner its application to the particular subject which is in question.

A given mass being urged in a definite direction by a given force, or known series of forces, for a given time, the object is to deduce quantitatively, by a geometrical process, the successive consequent changes of position which the body will experience in that time, the changes of position taken account of being only those which are directly affected by the force—those, namely, which occur in the direction which is that of the force; the transverse component of the motion (which the force does not tend to alter) being thus disregarded as irrelevant. We have, therefore, to represent change of position as consequent on velocity, which is changing at each instant, and change of velocity as consequent on force, which may be changing at each instant; and this when the force at each instant is dependent either on the position or the velocity of the body.

First, as regards velocity, referring to Plate I. (Fig. 1), let the base A B represent time to scale; and let it be drawn in a direction at right angles to that in which the body is supposed to move and the force to act, so that any ordinate drawn to it will be in the direction of the force. Let the scaled length of the ordinate $_mt\,_mp$ at any instant of time $_mt$, define the position of the body (*i.e.* its distance from the base) at that instant, the scales of the base and of the ordinate expressing the terms in which the velocity is rated, as *e.g.* feet per second; then if the body has at that instant a velocity towards or from the base, a line pp drawn through $_mp$ with due inclination upward or downward, will represent the velocity, since the inclination of the line will show how much the body recedes from or approaches the base in a given time. And if the velocity remain unchanged from $_mt$ to $_nt$, then the point $_np$, at which the inclined line pp cuts the ordinate planted at $_nt$, will define the position of the body at the instant $_nt$.

It is easy to see how we may thus also express the effect of a known small change of velocity taking place in a known and small interval of time. For, referring to Fig. 2, let

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the time from ${}_mt$ to ${}_nt$ be the interval, and let ${}_mv$ be the mean velocity of the body at ${}_mt$, that is to say the mean taken for a time, equal to the interval taken half before and half after ${}_mt$, and let ${}_nv$ be similarly the mean of the altered velocity at ${}_nt$. The result of this will be expressed by first drawing through ${}_mp$ on the ordinate at ${}_mt$, as before, a line with the inclination which represents ${}_mv$, and then drawing a second line with the inclination which represent ${}_nv$, across the ordinate at ${}_nt$, at such a height as to intersect the former line at the middle of the interval between ${}_mt$ and ${}_nt$. The point ${}_np$, where this second line cuts the ordinate at ${}_nt$, defines the position of the body at the instant ${}_nt$, and the two inclined lines are tangents to the curve by which the instantaneous position of the body would be continuously defined, and which might be called the curve of motion.

This process may be carried on *sine limite*, as long as we know the successive changes of the velocity; and we have now to see how we can conveniently express geometrically these successive changes, as the consequences of the forces which act on the body at each instant, in the direction of the ordinates.

To draw with exactness a velocity-inclination, it is advisable to determine its direction on a large scale—that is to say, to derive it from the change of position which the velocity would produce in a long time-interval, instead of in a short one, laying off these on an independent pair of axes, set out on some convenient part of the paper, and parallel to the base A B and its ordinates respectively; and then, with a parallel ruler, transfer the line, with its direction thus determined, to its appropriate ordinate station.

The same geometrical construction renders it easy to introduce any successive known changes of velocity, in terms homogeneous with those by which the original velocity was expressed.

To trace the whole process, for example, in Figs. 3 and 4: if ${}_qt$, ${}_rt$, ${}_st$, be successive ordinate-stations at successive small equal time-intervals, and if C P be the long time-interval or base,—then if ${}_qv$, the velocity (say) at the instant ${}_qt$ be known, the appropriate inclination may be determined with exactness by marking off on the vertical C D a point ${}_q'p$ such that the height C ${}_q'p$ is the travel due to the velocity ${}_qv$, if continued throughout the time represented by C P. Then the line P ${}_q'p$ gives the inclination which is to be carried by the parallel ruler to the ordinate at ${}_qt$, and which will form the tangent to the curve of motion at ${}_qp$. The vertical C D will, from its use, be termed the directrix. Again, if during the interval between ${}_qt$ and ${}_rt$, a known increment or decrement (say a decrement) of mean velocity takes place, the change of inclination due to this may be expressed by marking off the point ${}_r'p$ on the directrix, so that the interval ${}_q'p\,{}_r'p$ represents the decrement of velocity in the same way as C ${}_q'p$ represented the velocity ${}_qv$. Then the inclination of the line P ${}_r'p$ is that appropriate to ${}_rv$, and the

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line itself will form the tangent to the curve of motion at $_{r}t$ in the manner already described, and so on for any number of known changes.

Thus far the construction in Fig. 3 has only served to facilitate and give exactness and extension to the geometrical operation previously described. The dynamical condition which from the successive changes of velocity and inclination deduces the forces which occasion them has now to be introduced.

Since we are dealing with successive equal small unit-intervals of time, the changes of velocity are throughout plainly proportional to the forces which produce them; *i.e.* each change is proportional to the mean force which operates during the corresponding interval. The unit-interval may be conveniently called Δt.

Now, these changes of velocity are, by construction, proportional also to the successive spaces $_{q}'p\,_{r}'p$, $_{r}'p\,_{s}'p$, &c., and it is evident that the mean forces, if known, must be capable of being represented geometrically to scale in such a manner, or that the length of the base C P may be so selected, that the spaces $_{q}'p\,_{r}'p$, &c., instead of being only *proportional to the forces* shall be *equal to the geometrical representations of the forces.*

Moreover, the mean force during each interval is readily determinable, if the actual forces operating at successive instants are known or determinable. For let these instantaneous forces expressed to scale be used as ordinates at the successive instants $_{q}t$, $_{r}t$, $_{s}t$, &c., so as to give the points $_{q}f\,_{r}f\,_{s}f$, &c. Then a fair line drawn through these points will constitute what will be called the force curve; and it is obvious that the mean force during any given time-interval will be expressed by the line which, standing on the interval as base, will define a rectangle, the area of which is equal to the curvilinear area of the corresponding segment of the force curve. This line will be very nearly given by the ordinate to the force curve at the middle point of the interval; and the true mean may be obtained without appreciable error by help of the proposition that when any small segment of a curve is cut off by a chord, then, if we circumscribe the segment by a rectangle enclosed between the chord and a tangent parallel to it, the area of the part between the curve and the chord is two-thirds, the area of the remainder between the curve and the tangent is one-third, of the area of the rectangle, so that the true mean ordinate to the force curve for any interval, is that measured to the middle point of the curve, plus or minus one-third of the maximum versed sine between the curve and the chord drawn through the top of the adjacent ordinates.

Thus having duly adapted the length of the time-base C P, to the ordinate-scale of the force curve, we can take in a pair of dividers, step by step, the successive mean ordinates of the force curve determined in the manner just described, and apply each in

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its turn on the directrix, so as to fix successively the points $_r'p$, $_s'p$, &c., the starting point $_q'p$ being already known or determined; and thus, knowing the force curve, we are enabled by the process which has been described to determine the successive points $_rp$, $_sp$, &c., the points in fact which, if a fair line be drawn through them, constitute the complete curve of motion, or, as it may also be called, the curve of position, since it shows what will be the position attained at any instant, by the body acted on by the assigned forces; this is, in effect, a complete solution of the problem.

I said that the intersection of the consecutive tangents should be placed midway between the successive ordinate stations; and this rule is so nearly correct, that, in a general way, it may, for convenience sake, be adhered to. Strictly speaking, however, the intersection ought to be, not at this station, but at one which is never far from it, namely, that which denotes the centre of gravity of the segment of the force curve area included in Δt. This station is readily obtained, with exactness, by the following simple geometrical construction, exhibited in Plate II. (Fig. 6).

Let h and $_1h$ be two consecutive ordinates of the force curve; h the one which has already been determined, $_1h$ the following one, which is approximately known, and the exact value of which is sought; the vertical which bisects Δt, meeting the approximately fixed curve in s, will be already part of the figure. Draw a horizontal line $l\,m$ through the top of the shorter of the two ordinates, trisect on A B that half of Δt which is on the side towards the longer ordinate, join s and the point which marks the first step in the trisection; then the station of the C G—that, namely, at which the tangents ought to intersect—is fixed by the point where the line thus drawn cuts $l\,m$. The construction is so simple that it can be made with sufficient exactness by hand.

The proposition which fixes the intersection of the tangents at the station of the centre of gravity of the area, is one of much larger application, and is rigorous, and is also I believe new; it is true, not merely for a force-area of quasi-infinitesimal length, but for one of whatever length, and however irregular the curve which bounds it.

The demonstration is given in the Appendix, but it may be as well to state the proposition in its most complete form, which is as follows:—Adhering to the geometrical representation of dynamical action, which has been already employed, then, however irregular the force curve may be, if we count up the result at the end of a given time t, not only will the total change of tangential direction in the curve of motion be proportional to the total area of the force curve standing over that part of the abscissa which represents t, but the position also of the body, or the ordinate of the curve of motion at the end of t will be correctly defined by drawing the new tangent so as to intersect

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the initial tangent at a station coincident with that which marks the centre of gravity of the intervening force-curve area.

The process I have here described may be termed graphic integration by tangents. I now proceed to apply it to the equation of a ship's rolling in a sea-way.

The forces I shall take account of in treating of the question will, with a view to simplicity, be limited to those two principal ones to which I have already adverted, namely (1) the ship's "righting force," or "moment," as dependent on her inclination relatively to the wave slope at each instant, including also any speciality in her curve of stability; (2) the "resistance" she experiences while in motion, as dependent on her angular velocity.

I will first explain briefly how these two forces are measured in their relation to the problem; the application of the method to the determination of the motion of a given ship in a given sea-way will then take its departure from the abstract symbolical expression of the operation of these forces, which constitutes the differential equation of the motion; interpreting it, and tracing its results in the more intelligible language of ordinary geometry.

First, as regards righting moment, we may proceed on the two following propositions, as now generally admitted: (1.) Assuming the ship to be "stable," and, for convenience of description, understanding by this that she carries her masts upright when at rest in still water, she will, when floating broadside on in a sea-way, be always seeking to place her masts upright, or normal to the "effective" wave slope. With regard to the exact determination of the "effective wave slope," which if treated rigorously involves some intricate considerations, it is enough to state here, that if the ship is of small dimensions relatively to the wave length, the effective wave slope does not differ materially from the surface wave slope, and may at all events be practically regarded as proportionate to it.* But, for shortness, as the difference between the two is irrelevant to the present subject, we may treat the surface wave slope as being also the effective wave slope. (2.) When the ship's masts at any instant, instead of being upright to the wave slope, deviate from that position by any given angle, the force or "moment" by which she is urged towards that position (it may be fairly called the "*righting* moment," though it may occasionally be tending to increase the absolute inclination) is the same as the righting moment by which she is urged to become upright when inclined to the same extent in still water. Here, too, the proposition is open to minor exceptions; but these may be disregarded, not only because they are minor, but also because they are irrelevant. The correctness

* I have discussed this subject at some length in a Paper read to this Institution in 1873.

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of the method, it will be seen, is independent of the correctness of the suppositions made in framing the equation which it is used to interpret.

The ship's "relative inclination"—that is, her inclination relatively to the wave slope, which is also the difference between her "absolute inclination" referred to the horizon and the local inclination of the wave—supplies, as has been said, the primary measure of her righting force; and, with ships of ordinary form, this may be taken as the product of her weight, her metacentric height, and her relative inclination; but for ships with high upright sides, or again for ships with low freeboard, when the inclination is great it is necessary to refer to the ship's curve of stability in order to obtain the correct factor, to be substituted for the product of the metacentric height and the inclination.

We turn next to the force, or moment of resistance, experienced by the ship while rolling, which is a secondary or derivative force, attributable to the speed with which her hull is rotating in the water. I have shown at much length elsewhere, in connection with much remarkable experimental verification, that the resistance of a ship, while rolling in still water, is in effect expressible by two terms, one of which varies as the angular velocity, the other as the square of that velocity; and it will be convenient to regard this as actually proved, since it makes it easier to give living reality to the illustration of the method of employing the terms. For the present, the ship's still-water resistance is the best measure we possess of her resistance while rolling in a sea-way.

The values of the two terms, as appropriate to any particular ship, are determined approximately by rolling the ship in still water, by running a sufficient number of men from side to side, keeping time with the ship's oscillations, and, when the maximum range has been reached, stopping the men and allowing the oscillation to be extinguished by resistance, the progress of the extinction being recorded either by automatic apparatus, or by careful observations with battens. To deduce the co-efficients of resistance, the successive amplitudes or ranges are used as ordinates, stationed at corresponding time-intervals on a base line, and the result is a curve called the "curve of extinction," the mathematical analysis of which gives the values of the terms which express the law of resistance.

I will proceed now to the exposition of the actual process. The equation of rolling motion to be integrated is, in its most complete form, as follows:

$$-\frac{d^2\theta}{dt^2} = \frac{\pi^2}{T^2}\left\{f(\theta - {}'\theta) + R\right\},$$

Here θ is the ship's absolute inclination, $'\theta$ the inclination of the wave, and

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$\therefore$ $(\theta - {}'\theta)$ is her inclination relatively to the wave slope, or the ship's "relative inclination;" the term $f\ (\theta - {}'\theta)$ signifies that function of the relative inclination, which in the curve of stability, is assigned to the particular inclination, and expresses the righting moment of the ship when so inclined.

T is the time, in seconds, occupied by the ship in performing a single swing when rolling to moderate angles in still water, being half of what is commonly called the "metacentric period."

R is the effective "moment of resistance" which the ship is at the instant experiencing when rolling with her existing angular velocity, expressed in terms homogeneous with those in which, in the curve of stability, $f\ (\theta - {}'\theta)$ expresses the righting moment. Both terms alike in fact, when coupled with their co-efficients $\frac{\pi^2}{T}$, express "so many foot-tons $\times \frac{g}{W \rho^2}$," where W is the ship's weight in tons, ρ her radius of gyration, expressed in feet, as g also usually is. The abstract value of R is $k^1 \frac{d\theta}{dt} \pm k_2 \frac{d\theta^2}{dt^2}$ where k_1 and k_2 will have values appropriate to the particular ship in question, deduced from her curve of extinction; and observe that the $\pm$ sign must be understood to mean that the sign of the second term, which, being a square, would in itself always appear positive, must change in company with that of the first term.

The complete equation may be translated into popular language as follows: Change of ship's angular velocity towards position of rest effected in a given small unit-interval of time, is proportional to the mean righting moment due to the ship's relative inclination, minus the mean moment of resistance due to her angular velocity experienced by her during the unit-interval. And I proceed to explain in accordance with the preliminary exposition of the method, how that proportional change of velocity, and its result on the ship's position, can be expressed geometrically by means of geometrical expressions of the righting force and of the resistance. The righting force being, by help of the curve of stability, deduced from the ship's change of inclination, coupled with the wave's change of inclination; and the resistance being deduced from her angular velocity by help of the appropriate co-efficients supplied by the still-water oscillation.

We proceed as follows:—Draw the base line A B, Plate I. (Fig. 5), to represent time, and divide it off into a series of equal spaces by vertical lines drawn through, making the spaces represent small unit-intervals of time of convenient length, which will be designated as $\underset{1}{\Delta} t$, $\underset{2}{\Delta} t$, &c., numbered consecutively, while the positions or ordinate stations will be designated as ${}_0t$, ${}_1t$, ${}_2t$, &c. The inclinations at each instant,

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whether of the ship or of the wave, are to be expressed as ordinates to a scale of degrees; those above the line being positive, those below it negative.

Let the curve marked "curve of wave slopes"* represent those slopes as they will be encountered by the ship at the successive time-intervals denoted by $\Delta_1 t$, $\Delta_2 t$, &c. It is proposed to determine and indicate the ship's absolute inclinations, which grow out of the circumstances, as time, and the varying wave slopes which time brings proceed.

These absolute inclinations will be represented by a curve analogous in general character to the curve of wave slopes, to which indeed it will on the whole exhibit special local conformity, but to which, according to circumstances, it may sometimes exhibit local antagonism. This I will call the "curve of rolling," or the "curve of "inclinations." This curve, which gradually grows out of the integration, is shown in the figure as completed.

The difference between the ordinates of the two curves, at any instant, gives the ship's relative inclination at that instant; and it will be remembered, that it is on this relative inclination that the righting force depends. The angular velocity of the ship's change of inclination is obviously expressed by the tangential direction of the curve of inclination, in the same manner as in the preliminary explanation of the method the linear velocity of the body was expressed by the tangential direction of the curve of position.

To carry on the process, we must now introduce two auxiliary curves, as they may be termed.

Plate II. (Fig. 7.)—The ship's "curve of stability," which supplies, as has been explained, her righting moment, as due to her relative inclination at any instant. In this, the scale of angles which forms the base, is the same as that used in the curve of wave slopes and the curve of inclinations. The ordinates corresponding with given inclinations express the righting moments at those inclinations, to the same scale which will be employed in the graphic process.

Fig. 8.—The "resistance indicator," which supplies the moment of resistance experienced by the ship when moving with any given angular velocity. In this, the angular velocities on which the resistance depends are read off as abscissæ on the vertical axis C D, which will at the same time be employed as what was called the directrix in the preliminary explanation; the scale of angular velocity is such as to

* Observe: this line, though wave-like in its general appearance, represents, not the wave profile as a figure, but its local inclinations, indicated by ordinates proportioned to the inclinations.

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correspond with the length which will presently be assigned as that of the base C P, which is the companion axis to the directrix. The resistance ordinates corresponding with the angular velocities express force, on the same scale as that used in the curve of stability.

The geometrical construction of this curve is, as will be readily seen, conformable to the nature of the experimentally-determined dynamical conditions which it embodies, and which approximately express the relation of the resistance to the velocity. As has been already stated, the conditions embodied are—

$$R = k_1 \frac{d\theta}{dt} + k_2 \frac{d\theta^2}{dt^2}.$$

The first of these terms is expressed by the rectilineally-growing interval between the straight line C E and the axis C D, say by the ordinate segment de at any point d.

The second term is expressed by the parabolically-growing interval between the curve C F and the quasi-base C E, say by the ordinate remainder ef at the same point.

We now turn to the employment of these data in the geometrical solution of the dynamical equation.

That equation may be written thus, grouping the force-terms under the single symbol ϕ:

$$d(d\theta) : dt = \phi : \frac{T^2}{\pi^2 dt}$$

or substituting for the differential terms, small quantities virtually infinitesimal,

$$\Delta(\Delta\theta) : \Delta t = \phi : \frac{T^2}{\pi^2 \Delta t}$$

where Δt will be taken as the unit space in Fig. 5.

The ratio may be geometrically rendered and utilised as follows: In Fig. 8, let the length of the base line C P, drawn each way and ending at + P and − P be made $= \frac{T^2}{\pi^2 \Delta t}$. Returning to Fig. 5, let us assume that at the commencement of $\underset{1}{\Delta t}$, the ship has the absolute inclination ${}_0\theta$ and the angular velocity $\left(\frac{\Delta\theta}{\Delta t}\right)_0$; and this, in the manner which has already been explained, is represented by the position and tangential inclination of the line ${}_0p\ {}_1p$.

With a parallel ruler carry this inclination to Fig. 8, and draw it through + P or − P, till it cuts the directrix in ${}_0'p$; the line will pass through + P or − P, according as the velocity is positive or negative.

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The height $C_0'p$ on the directrix, is plainly proportional to the angular velocity; and the consideration just now referred to as governing the selection of the scale of angular velocity used in constructing the resistance curve, is, that $C_0'p$ or any height thus defined, and therefore proportional to the angular velocity given in the curve of inclinations, shall express that angular velocity correctly on the scale belonging to the curve of resistance.

The angular velocity being thus represented, and the length of the base P C being $\frac{T^2}{\pi^2 \Delta t}$, the geometrical expression of the dynamic action is as follows: If we cut off below $_0p$ a distance which expresses $_1\phi$ to scale, and thus define a second point $_1p'$, the tangential inclination of the new line P_1p' will represent the angular velocity which will exist at the end of $\Delta_1 t$. Now ϕ consists of $f(\theta - '\theta) + R$; of which terms, the former expresses the ship's righting moment, the second her moment of resistance, each taken as representing its mean value during the interval Δt which is for the instant under consideration.

To obtain this mean in each case systematically, it is convenient to construct, step by step as the integration proceeds, what I have called the "force curve"—a curve the ordinates of which, at the end of each Δt, shall represent the sum of these two forces as in combination; when these terminal ordinates have been defined, the "mean" is easily taken. The ordinates will necessarily consist of two segments, one of which will represent the resistance, the other the righting force; and a curve traced through the successive points which mark the division of the segments, will interestingly show how the two elements of force vary independently as the rolling goes on.

The method by which each element is determined, involves nominally, several steps of progressive correction; but in reality, it will be found that, owing to the smallness and the obviousness of the corrections, each determination can be made in a single step. I will, however, trace the method rigorously for the first interval $\Delta_1 t$.

To determine $f(\theta - '\theta)$, observe that $(\theta - '\theta)$ at each station is, the ordinate cut off between the curve of wave slopes and the curve of inclinations. The former curve is already fixed throughout, and is therefore fixed at both the beginning and end of $\Delta_1 t$. The ordinate of the curve of inclinations is also known at the beginning of $\Delta_1 t$, for it is given as the starting point for the "curve of inclination;" and at the beginning of every subsequent Δt it will be alike known, for it will have been already determined by the progress of the integration. And it is known, not indeed exactly, but very approximately at the end of $\Delta_1 t$, since the tangential inclination of the curve of inclinations is given at

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the commencement of $\underset{1}{\Delta} t$, and from the nature of the circumstances, it is easy to see whether this inclination is on the increase or on the decrease, and the corresponding increment of the ordinate will be necessarily small, and can be estimated approximately. Take then in a pair of dividers, the exact ordinate length between the two curves at ${}_0t$, and the approximately estimated ordinate length at ${}_1t$, and apply the dividers thus charged as consecutive abscissæ to the curve of stability. The corresponding ordinate of that curve, is in each case the required value of $f(\theta - {}'\theta)$, and observe that it will have a positive sign, as tending to increase positive velocities and inclinations and diminish negative ones when $(\theta - {}'\theta)$ is negative; or *vice versâ.*

To determine the terminal values of R at the beginning and end of $\underset{1}{\Delta} t$, observe that the ordinate of the "curve of resistance," corresponding with the point ${}_0p$ in the directrix, is the value of R at the beginning of $\underset{1}{\Delta} t$; and if we estimate approximately the change of velocity which will ensue during $\underset{1}{\Delta} t$, we shall approximately fix the point ${}_1p'$ on the directrix, and the ordinate of the curve of resistance corresponding with ${}_1p$ will be the approximate value of R at the end of $\underset{1}{\Delta} t$. The approximation here is hardly so close as that by which the second value of $(\theta - {}'\theta)$ was estimated, yet even here it will be found easy to estimate the result so closely as to require merely nominal subsequent correction. Observe that R is always negative when the velocity is positive; and *vice versâ.*

Having obtained these two terminal values of $f(\theta - {}'\theta)$ and of R, treat their sum as the ordinate of the "force curve" at each point, placing the value of R next the base, and the other on the top of it, bearing in mind at the same time their approximate signs. Connecting the tops of these ordinates, we have formed with close approximation the first segment of the force curve.

We are now in a position to determine the ordinate length which represents the mean value of ϕ during the interval $\underset{1}{\Delta} t$. Were the force curve a straight line, the ordinate length would be almost precisely the length of the force curve ordinate at the middle point of $\underset{1}{\Delta} t$; and, as already explained, we can make a sufficient correction for the curvature, by treating the area of the flat curvilinear segment as two-thirds of the circumscribing rectangle.

Take now in a pair of dividers the middle ordinate thus corrected, and apply the length to the point ${}_0p'$ in the directrix, as an addition, or as a deduction, according to its appropriate sign. This will fix with close precision the point ${}_1p'$, which has been already provisionally fixed.

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If the line $P\,{}_1p'$ be now drawn, the difference of its tangential inclination from that of $P\,{}_0p'$ represents with close approximation (indeed exactly, if the provisional estimate has been judiciously made) the change of velocity which has ensued during $\underset{1}{\Delta}\,t$, and a line parallel to $P\,{}_0p'$, will be the tangent to the curve of inclination at ${}_1t$. Draw, therefore, this tangent across the ordinate ${}_1t$, at such a height that it shall intersect the previous tangent at the station of the centre of gravity of the segment area of the force curve corresponding with $\underset{1}{\Delta}\,t$. This height is the first approximate value of the ordinate to the curve of inclinations at that point.

We can now see with certainty whether any, and what, corrections are required in the provisionally-estimated values of the ordinate, and of the tangential direction of the curve of inclinations at ${}_1t$; and the required correction, if rationally made in the light of the process already performed, will give the true result with substantial exactness. The process can be carried on pretty rapidly from ${}_1t$ to ${}_2t$, and so on, so as to form the curve of inclinations for any required distance.

By help of the proposition which fixes the true position for the intersection of the tangents, the process described is theoretically rigorous, and does not introduce any errors but those which may be involved in the construction of the equation, or which may be unavoidable geometrically: the latter, however, are in reality extremely small; they are only such as may be inherent in the use or performance of parallel rulers or dividers, and in the difficulty of drawing a straight line through a point, so as to carry on the curve from tangent to tangent. That no large error is likely thus to arise will be immediately ascertained by any one who will take the trouble to apply the method of tangents to the ordinary case of a body falling by gravity, *i.e.* when the force is constant; he will at once perceive that the curve constructed gives results in almost exact accordance with the usual formulæ $v = g\,t$ and $h = \frac{v^2}{2\,g}$. The resulting errors will probably be far less serious than one which is so continually regarded with indifference by those who (often not unwisely, when the convenience of the step is considered) are in the habit of using $\frac{32'}{1''^2}$ instead of $\frac{32'\cdot17}{1''^2}$ as the working value of g.

The exactness of the results which the method will yield in skilful and appreciative hands is witnessed by the instances given in Fig. 9 (Plate II.) to Fig. 10 (Plate III.)

The dotted lines are enlarged copies of the extinction diagrams of H.M.S. *Inconstant* and *Devastation*, the originals of which were drawn automatically. The abscissæ in each represent seconds, and the ordinates of the undulating line represent the

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changing inclinations of the ship as she continued to roll until the original impulse which set her rolling was exhausted. By approximate general formulæ which I have framed, the ship's co-efficients of resistance were deduced from the "curves of extinction," Figs. 11 and 12 (Plate III.), which these diagrams supplied. By applying the method I have been describing, the whole extinction diagram has been in each case reproduced, as shown in plain black lines. The close accordance between the dotted and plain lines is a proof that the process by which it is worked out does not involve serious error.

Assuming the method to be correct, it has become possible, by means of it, to apply the theoretical conditions which govern the rolling of ships (so far as these are yet known), to the behaviour of any given ship in any possible series of waves, however turbulent or irregular, a result absolutely unapproachable by regular analytical methods. And this circumstance opens the road to a real comparison between the actual behaviour of a ship in a given sea-way (assuming the behaviour and the sea-way to have been truthfully recorded), and the behaviour which theory would have assigned to her under the circumstances. I believe it will be only by persistent, and I must add, laborious comparisons of this kind, that we shall learn, what hitherto unknown conditions may remain to be taken account of, and what corrections and modifications it may be necessary to introduce in relation to those conditions which have been already investigated and reduced to law.*

APPENDIX.

Proof that any pair of tangents to the curve of motion intersect at the ordinate station which marks the centre of gravity of the force curve area included between the stations of the ordinates to the points of contact. The proposition may be stated as follows. Plate III. (Fig. 13):—

Let AB be the time-base; i, i, i, i, the curve of motion; ${}_0t$ and ${}_1t$ the ordinate station to the points of contact of its two tangents ${}_0p\,{}_0'p$ and ${}_1p\,{}_1'p$. The ordinate drawn through C, the point of intersection of the tangents, cuts the centre of gravity of the corresponding area of the force curve $ffff$.

For, F being the force-ordinate at each instant, the velocity created in the whole time ${}_1t$ will be $V = \int_{{}_1t}^{{}_0t} F\,dt$, which is also the value of the entire area of the force curve, say A; hence V = A.

* I take this opportunity of expressing my thanks to Mr. P. Watts and Mr. J. R. Perrett, (of the Constructor's Department at the Admiralty), of whose able services as my assistants, in succession, I have by the courtesy of the Department been permitted to avail myself; and who have aided me in this and allied investigations, not merely as skilled draftsmen, but as entering effectively into the objects and meaning of the work. The reconstructed extinction diagrams of the *Devastation* and the *Inconstant* worked out by my method by Mr. Perrett, and which appear as illustrations of it in Plates II. and III., are remarkable proofs, at once of his appreciation, accuracy, and skill, and of the soundness of the method itself.

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Now this velocity is plainly expressible by, and is equal to, the difference between the directions of initial and final tangents; and therefore, ${}_2t$ being the abscissa value for the intersection of the tangents, we have ${}_0p\,{}_1'p = \mathrm{V}\,{}_2t = \mathrm{A}\,{}_2t$.

Again, taking notice of the circumstance that $'p\,''p$ is the interval between any two consecutive tangents corresponding with the time increment $d\,t$ and with the abscissa value t, it is obvious that ${}_0p\,{}_1p$ has another value, or ${}_0p\,{}_1p = \int_{{}_1t}^{{}_0t} t\,d\,v$, since the interval between the tangents is the velocity increment corresponding to $d\,t$.

But $d\,v = \mathrm{F}\,d\,t$, so that ${}_0p\,{}_1p = \int_{{}_1t}^{{}_0t} t\,\mathrm{F}\,d\,t$, which is also the integral value of the moment of A acting with its C G distance as leverage, or $\mathrm{A} \times \mathrm{CG}$. Hence $\mathrm{A} \times \mathrm{CG} = \mathrm{A}\,{}_2t$, or ${}_2t = \mathrm{CG}$.

DISCUSSION.

Dr. J. Woolley, F.R.A.S.: I merely wish to observe that this, of course, is a most difficult subject to follow exactly when one has seen it for the first time; but, as far as I have been able to follow it by Mr. Froude's explanation, it seems to me to be founded on strictly sound scientific principles. I think it would be a great pity if we dismissed this Paper without expressing that some of us, at all events, do fully believe that Mr. Froude has succeeded in solving a most difficult problem which no analytical method has yet been able to reduce. It is true that an approximate solution by an analytical method has given us a great deal of information of importance,—and more, perhaps, than we can obtain by the strict integration. Still it is very important and desirable that in many cases we should be able to get a strict integration of this difficult equation; and I believe, as far as I was able to follow it, that Mr. Froude's process does give us that.

Mr. J. Scott Russell, F.R.S.: I quite believe, indeed I am perfectly satisfied, that what we call the geometrical process of integration is only to be applied to this subject in order to give its perfect solution. I am not sure that I quite followed every step in Mr. Froude's process, but as I have reason to know the process such as he adopts is perfectly effective for that and similar problems, I entirely trust to his experience to believe that it is effectual in this case of his own application.

Mr. W. H. White: I should like to ask Mr. Froude one question. The most difficult problem, so far as I know, which is to be met with in the analytical investigation, is the determination of the effective wave slope. Mr. Froude's curve of wave slopes as ascertained by his automatic apparatus would be, I think, what we should call the effective wave slope. I should like to ask whether in the trials of the *Devastation* or the *Greyhound*, when the wave-slope curve was traced out by the apparatus, Mr. Froude was able to compare the inclinations so traced with the surface inclinations of the waves which were observed at that time; and also whether he is able to tell us how far the original assumption that the effective wave slope should be taken at the level of the ship's centre of buoyancy has departed from the facts as he has observed them, and whether his later investigations, which we have had the pleasure of reading in the *Transactions*, agreed with the observed facts.

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Mr. W. FROUDE, F.R.S.: Speaking generally, the approximation is very close. The waves hitherto encountered have always been so turbulent, that we have never had a steady broadside-sea in which the comparison could be made with real exactness. The shape of the *Devastation* is peculiar, because she has a great overhanging raft of a stern, and a lump of a wave passing under the stern will affect her inclination without producing a strictly corresponding effect on the apparatus, which only speaks veraciously when the ship is operated on throughout her whole length by uniformly-shaped waves. The apparatus gives us what purports to be the effective wave slope. In some cases we also independently determined simultaneously the surface-height of the waves; and the height, as observed, was always greater than that given by the apparatus, and this corresponds with the fact that the effective wave slope is considerably below the surface wave slope. For this particular illustration I did not go into that question. It is a very difficult and intricate one. I merely assumed a wave curve of perfectly regular form to work out the illustration. I hope some day to be able to get more regular waves, and when that is done, we shall have a better opportunity of carrying out the comparison more correctly.

The PRESIDENT: I am sure we must all join, after what has fallen from Doctor Woolley and Mr. Scott Russell, in thanking Mr. Froude for his very able Paper on this difficult but interesting subject.

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ON A METHOD OF OBTAINING MOTIVE POWER FROM WAVE MOTION.*

By B. Tower, Esq.

[Read at the Sixteenth Session of the Institution of Naval Architects, 20th March, 1875; the Right Hon. Lord Hampton, G.C.B., D.C.L., President, in the Chair.]

I propose to lay before you to-night the results of an experimental and theoretical enquiry into the possibility of obtaining motive power from the motion of a ship in waves, for the purpose of actuating machinery on board.

This enquiry originated in the proposals of Mr. Spencer Deverell, of Portland, Australia, whose brother, Mr. W. Deverell, showed his confidence in the scheme by coming home from the Antipodes for the purpose of promulgating it.

Mr. Deverell's original proposition was to suspend a heavy weight on board a ship by means of springs, and to obtain motive power by the oscillation of this weight through a distance not more than the height of the waves.

On looking into the question, it appeared to me that since the centrifugal force of wave motion in a vertical direction is alternately added to, and subtracted from, the force of gravity thereby causing a virtual variation of the intensity of that force, that broadly the question resolved itself into this: Supposing the force of gravity to vary in intensity at regular intervals—that is, to become alternately greater and less than its normal amount—what is the best means to obtain the maximum amount of energy from a given weight oscillating under the influence of these variations? For example, supposing the force of gravity to be for three seconds one-fifth greater, and for the next three seconds one-fifth less than its natural intensity, and suppose that we have a weight of 5 tons suspended by a spring, with an infinitely open scale, so that the spring will continue to exert a uniform upward force of 5 tons, no matter how far the weight moves up and down, it is clear that during the three seconds interval, during which gravity is one-fifth more than its normal intensity, the 5-ton weight will virtually weigh

* Received 2nd March, 1875.

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6 tons, and will thus exceed the upward force of the spring by a downward force of 1 ton; in the same way, when the force of gravity is one-fifth less, the weight will only weigh 4 tons, and the spring will then exert an unbalanced upward force of 1 ton. Now, as energy or power is defined as force moving through distance, it is clear that the quantity of energy or power to be obtained by this system will depend on the distance through which this weight is caused to move during each successive variation of gravity. Thus, supposing that during the *plus* interval it moves downwards through 1 foot, and during the *minus* interval it moves upwards through 1 foot, it is clear that during each of these intervals it will exert a force of 1 ton moved through 1 foot,—that is, 1 foot-ton; but if, instead of 1 foot, it moves through 10 feet, it will exert ten times the power—that is, 10 foot-tons; or, if it moved through 100 feet, it would exert 100 foot-tons during each interval of three seconds: in fact, other things being equal, the quantity of power to be obtained by such a system under such conditions would be simply and directly as the distance through which the weight moves. The fact that external force would have to be used to compel the weight to move through a greater distance than it would otherwise move through if left to itself, does not in any way alter this fact; for, theoretically, no power would be lost in causing the weight to oscillate through a great or any distance. All the energy consumed in the acceleration of the weight would be completely returned during its retardation.

Further consideration convinced me that this analogy was a strictly correct one; and that, other things being equal, the quantity of work to be obtained by a given weight under the influence of wave motion would depend simply on the distance through which the weight is caused to move during each wave interval. By adopting this principle I saw that it was possible to obtain a reasonable amount of power from a moderate weight, and was encouraged to pursue the subject and to put my conclusions to the proof in a working model. For this purpose I obtained a model boat, 6 feet long and 16 inches broad, with a displacement of about 80 pounds. Amidships on the deck of this model I fixed an upright standard 1 foot 3 inches high. Pivoted in its centre on the top of this standard was a spring consisting of a steel blade 4 feet long and 3 inches wide in the middle, tapering to nothing at each end, and $\frac{1}{16}$ inch thick. On the after end of this spring was fixed a 7-pound lead weight; to counterbalance this at the fore end, the spring was connected to another flat spring close to the deck of the model. Both of these springs were set to such a curve when unstrained, that the strain of the 7-pound weight was just sufficient to straighten them. The fore end of the spring was also connected to a system of double-acting rachet pauls, so that a motion of the end of the spring either upwards or downwards communicated rotation in one direction to a toothed wheel, which toothed wheel geared into a pinion; on the same axis as this pinion, and driven by it, was a

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grooved pulley; driven by this pulley was a long elastic round india-rubber cord, $\frac{1}{4}$ inch in diameter. This cord stretched the whole length of the model to the after end, and then passed over the stern over two guide pulleys, and thence under water to a groove on the enlarged boss of a screw, 8 inches in diameter and 12 inches pitch.

The india-rubber cord was thus at once a driving band for communicating the motion of the grooved pulley to the screw, and by its elasticity a reservoir of power whereby the intermittent motion of the grooved pulley was converted into a continuous motion of the screw. The 7-pound weight could oscillate through a vertical distance of 2 feet, and had a period of oscillation of about one second. The gearing was so adjusted that the force on the rachets necessary to drive the screw at full speed was just about equal to the tension of the spring when the weight was near its extreme upward or downward position; the weight was thus permitted to oscillate through its full range of 2 feet before any work was abstracted from it.

This model was evidently only suited for waves having the same period as that of the weight on the spring, namely, one second. I first experimented with it in a tank 30 feet long and 10 wide; in this tank I generated waves of as nearly the proper period as possible, artificially, but I found it impossible to set up a regular series of waves owing to the waves reflected from the end and sides of the tank meeting those which were advancing and causing a confused jumble; nevertheless my model made many voyages from one end of the tank to the other, accomplishing the distance in about half a minute, which is at the rate of about $\frac{6}{10}$ths of a knot per hour. Had it been possible to generate a set of regular waves, the model would have travelled with at least twice this speed; for when the model met with waves of the proper period the machinery worked with great energy, causing the screw to revolve at the rate of about 150 revolutions per minute, but this exhibition of energy was only occasional and only recurred when the waves happened to synchronise with the weight. I therefore determined to try the model at sea. I accordingly took it out in Torbay and followed in a boat. Mr. Froude, who has throughout taken a kindly interest in this enquiry, and has afforded me much valuable assistance in carrying it on, was present at this trial.

The result of this trial was much the same as that in the tank. When four or five waves of the proper period followed one another the machine worked with great vigour, causing the screw to go at the rate of about 150 revolutions per minute, but at other times it almost stopped. The average rate of the screw as counted for one minute was 40 revolutions, during which time the model moved ahead about 30 feet. The model had a tendency to come up head to wind, so that this progress was made against a head wind. The study of the action of this model clearly convinced me

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that I was right in my view that the work obtainable from a given weight is as the height through which the weight is caused to oscillate. In this instance, supposing the weight to oscillate through only one foot instead of two, and as before to give off its work only at the end of its oscillation, it is clear that the tension of the spring and consequently the force delivered on the rachets will be only half what it was with double the range of oscillation. Again, the work delivered by the system is equal to the work put into it, minus the friction. And the way in which work is put into it is by the spring actually tending to resist the vertical motion of the boat, by pulling up when the boat is descending and pushing down when it is ascending. The quantity of work put in by each upward or downward movement of the boat is equal to the mean tension of the spring multiplied into the distance through which the boat rises or falls, and the mean tension of the spring is as the range of oscillation of the weight, consequently the quantity of energy put into the apparatus is as the range of oscillation of the weight. The quantity of work per minute in foot-pounds which this apparatus is capable of, if actuated by a regular series of waves, is expressed by the equation—

$$W = \frac{60\,\pi^3\,h\,m\,H}{P^3 g} = \frac{57{\cdot}7\,h\,m\,H}{P^3}.$$

In which h is the effective height of the wave; m is the moving mass or weight; H is the height through which it oscillates; P is the period in seconds. Thus the work per minute is directly as the height of the waves, the mass of the weight, and the height through which it oscillates, and inversely as the cube of the period.

In the case of this model, when $h = \frac{1}{10}$th of a foot W = 80 foot-pounds per minute, which would be equal to drive the model about $1\frac{1}{4}$ knots per hour, and certainly when working with full vigour it seemed to be quite equal to this.

Though this model answered its purpose perfectly well in demonstrating the truth of my theoretical conclusions, the arrangement of the apparatus was clearly unsuitable for practical application on a larger scale. One serious defect under which it laboured was its being only adapted to one particular length of wave, and in order to make it adjustable to any length of wave it became necessary to provide means either to vary at will the strength of the spring or the weight; either of these would be difficult, and I therefore sought for some arrangement capable of adapting itself to any period. According to the theory, the weight has to be rising while the ship is passing from the point of maximum slope on the front of the wave over the crest to the point of maximum slope on the back of the wave, and should be falling from this point over the trough or hollow to the point of maximum slope on the front, when it should again begin to rise; and so long as these conditions are complied with, the nature of the mechanism by which it is affected does not affect the result providing that it is equally frictionless.

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These considerations led me to think that the best arrangement would be to put the weight on the end of a revolving arm, and to balance the weight, in all positions, by a spring acting on a crank; the weight would thus describe a circular path in a vertical plane, and the value of H would, of course, be the diameter of the circle. I also perceived, that if the weight revolved in the same plane and direction as the wave particles, so that the centrifugal force followed it all round, that the horizontal as well as the vertical oscillations would be utilized, and the power of the machine nearly doubled.

I have here a model of a machine constructed on this principle; it was originally intended only to utilize the vertical oscillations, and in it two 50-pound weights are employed, geared together, so as to cause them to revolve in opposite directions, in order that the horizontal forces might be neutralized; but, if it is desired to utilize the horizontal forces, the removal of a mitre-wheel in the centre allows the two weights to revolve in the same direction. When only the vertical oscillations are utilized, the same equation applies to this machine as to the first one. This machine, mounted on a see-saw plank, so that vertical oscillation could easily be given to it, has, at 40 revolutions per minute, actually delivered 1,600 foot-pounds per minute, or about $\frac{1}{20}$th of a horse-power on the brakes; the vertical oscillations imparted to the machine being about 6 inches high, the diameter of the circle described by the weights is 2 feet. This machine is an evident proof that the conclusion—that the power is as the height through which the weight oscillates—is a correct one; for it is clear, that, if with the same weight we increase the length of the arm, we in the same proportion increase the leverage with which the centrifugal force of the wave motion acts on the shaft to turn it; and, consequently, in the same proportion we increase the power of the machine.

Experiments at sea with this machine have, however, convinced me that ordinary waves are much too irregular to allow the machine to work with full effect, waves being generally a compound of two or three different sets one on the top of the other, the result being a considerable irregularity of oscillation. This machine is capable, at sea, of starting of itself, and of running and developing its full power so long as the irregularities of the wave motion are not too great for it, it being capable of adapting itself to a certain degree of irregularity; but when this degree of irregularity is exceeded, it stops and awaits another favourable opportunity for starting again. On one occasion, when the conditions were far from favourable, I found that these runs seldom exceeded about a dozen revolutions. In order to overcome this difficulty, arising from the irregularity of the waves, I have schemed an apparatus, which I have not yet been able to put in practice, but which will, I hope, compel the weighted arm always to keep at

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right angles to the centrifugal force of the wave motion, and thereby enable the machine always to exert its maximum power under all circumstances.

For this purpose I propose to employ an apparatus which I call a "feeler," which will consist of a weight mounted on an arm and balanced by a spring, in the same way as the weight is in the large machine before described; the feeler is, in fact, a counterpart of the large machine on a very much smaller scale. The length of the arm will be about one inch; it will be delicately pivoted to avoid friction, and as no work will be imposed upon it, it will always point in the direction of the centrifugal force of the wave motion, and being very short will be very quick and sensitive in following the varying direction of the force, and in accommodating itself to irregularities in the speed with which the direction varies. In order to make the indications of this instrument sensible to the large machine, so as to control its movements, and at the same time impose not the slightest work on the "feeler," I propose to employ a device by which I believe astronomical clocks are sometimes made to control the motion of large telescopes. In this apparatus a small arm, moved by and with the same angular velocity as the large machine, will follow a similar arm fixed on the "feeler." These two arms being in contact will close an electrical circuit, and their being separated will break it. They will be set so that the weighted arm of the large machine will be at right angles to the "feeler" when these two contact arms are just touching. The shaft carrying the weighted arm of the large machine will carry cranks, to which will be attached three hydraulic cylinders.

These hydraulic cylinders will be provided with ordinary slide valves; these valves will be connected with an air vessel or accumulator, containing water under a high pressure; another valve, actuated by an electro magnet, contained in the electric circuit before mentioned, will have the power of reversing the direction of the flow of water through the cylinders, so that in one position of the valve the cylinders will be taking water from the accumulator, and therefore acting as an engine, and accelerating the motion of the weighted arm; in the other position the cylinders will be delivering water into the accumulator and therefore acting as a pump, and absorbing work from the weighted arm, and will therefore retard its motion. The first position giving acceleration to the weighted arm will be the one consequent on the electrical circuit being broken, the second being the result of the circuit being closed. The effect of this will be that, if the weighted arm is in advance of its proper position at right angles to the "feeler," and consequently to the centrifugal force, its motion will be retarded; and if it is behind its proper position, it will be accelerated. Now, though the accelerative force is borrowed from the store of power contained in the accumulator, it will be repaid by the retarding action while the cylinders are acting as pumps; in addition to which the

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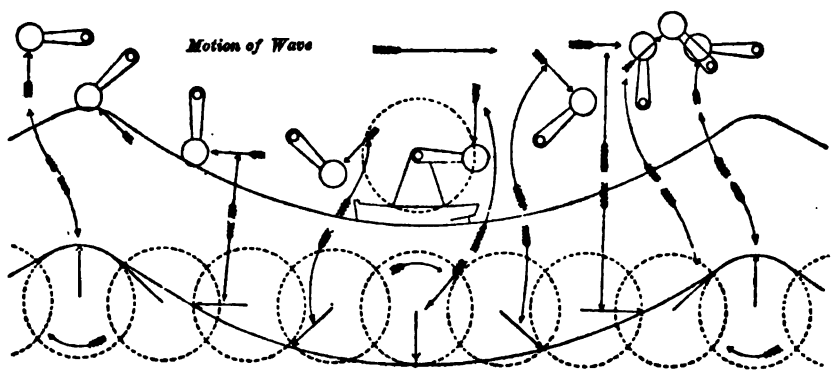
work put into the revolving weighted arm by the centrifugal force of the wave motion will also be expended in pumping water into the accumulator, which can be again expended in actuating a hydraulic engine for the purpose of driving a propeller, or of doing any other desired work.

The foregoing is intended as a rough sketch of what I consider as a possible way for controlling the action of the machine, rather than as a matured plan, though I think that it is in a general way the direction which I should follow if ever I have the opportunity of working the thing out practically.



The above diagram shows the position of the vessel and of its revolving arm on all parts of a wave, the arrows show the direction of the centrifugal force of the wave motion according to the generally received theory. This force is upwards on the crests, downward in the hollows, and horizontal midway between the crests and hollows. If the weighted arm is compelled to assume successive angular positions so that it is always at right angles to the force, it is evident that the force will be continually acting to cause the arm to rotate.

It is easy to see how the work is taken out of the wave, for when the vessel is descending, the weight is performing the upper half of its revolution, and is consequently exerting an upward centrifugal force; and when the vessel is ascending, the centrifugal force is pushing down and resisting the vessel's ascent, so that the revolving weight affords a resistance against which the vessel can push, just as if we had a fixed point in space. This consideration of the manner in which the work is taken out of the wave, led me to think, when I first looked into it, that the centrifugal force of the weight would tend to prevent the oscillations of the ship, on the extent of which we depend for our power, and that this would seriously limit the amount of power applicable to a given ship; but further investigation showed me, rather to my surprise, that this yielding of the ship to the centrifugal force of the weight would, in ordinary cases,

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instead of diminishing, actually increase the range of oscillation of the ship, and consequently the power exerted by the machine.

This apparent paradox may be explained by the following considerations:—Supposing the natural period of vertical oscillation of a ship is the same as that of the waves, we know that each wave will give additional energy to the ship's vertical oscillations, and that were it not for the friction of the water absorbing this energy, that the ship would rapidly acquire such an oscillation as would either lift her completely out of the water or bury her beneath it. If we analyze the way in which these successive increments of oscillation are given to this ship, we shall see that it is the same as that by which the oscillation is given to the weight in the wave machine; in fact, that the ship will be at its lowest point when the weight is at its lowest, and at its highest when the weight is at its highest. Supposing such a ship to have a wave machine on board, it is certain that the wave machine would do work due to the actual oscillations of the ship, and as these oscillations would be greater than the weight of the waves, owing to the fact of the waves synchronising with the ship's natural period, it is also certain that the wave machine would do more work in proportion to the degree in which the vertical oscillations of the ship exceeded those of the waves. In such a case the whole weight of the ship acts as a wave machine and absorbs power from the waves, which is given to the machine on board in the shape of an oscillation of the ship of increased amplitude.

Now, in all ordinary cases, the period of vertical oscillation of ships is less than the period of waves large enough to give them sensible motion, and consequently less than the period of the wave machine, so that the depressions and elevations given to the ship by the centrifugal force of the weight will coincide with the degree and direction of this centrifugal force. Now we have seen already that this is what happens in the case of the ship having the same natural period as the waves. In fact, the wave machine compels the ship to synchronise with the waves in its vertical oscillation in spite of its natural period, and consequently to utilize the whole of the ship's weight as wave machine weight.

Although I have confined myself entirely to the theoretical view of the question in this Paper, and I am not yet in a position, neither do I wish, to discuss the nature or possibilities of the practical construction and mechanical arrangement of a machine working on the principles herein enunciated, it will nevertheless be interesting, before leaving the subject, to take a glance at what may be a possibility of the future in its application and utility.

Let us suppose an ordinary sailing ship of say 1,100 tons displacement when loaded, to which it is proposed to apply a wave-power machine to have a moving weight of 100

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tons; suppose the ship to be loaded before taking this weight on board till she displaces 1,000 tons, and that thus loaded, she has a metacentric height of 4 feet; now the question is what is the largest diameter of circle through which the 100 tons may be caused to swing, without endangering the stability of the ship?

In order that 100 tons may balance 1,000, it must have a lever arm ten times longer than the 1,000 tons has, in this case the centre of gravity of the 1,000 tons is 4 feet below the metacentre or virtual fulcrum; it is clear, therefore, that the 100 tons would have to be 40 feet above the metacentre just to balance the 1,000 tons, so that then the ship would be just in tottering equilibrium, and this would be the utmost limit to which the weight might approach, but it would certainly not be safe to approach it too nearly, say not nearer than 14 or 15 feet; now the metacentre would probably be about this distance above the bottom of the ship's hold, so that if the weight swept through a circle of 40 feet diameter, the lowest part in the circle being close to the bottom of the hold, the highest would be sufficiently within the limit not to endanger the safety of the ship; though of course if the wind was sufficiently good in intensity and direction to make it worth while to carry a press of canvas, the requisite stability for that purpose would be secured by locking the weight in its lowest position.

Let us suppose our ship to be outward bound to a port on the west coast of America, and that at the mouth of the Channel she meets with south-west gales—a not uncommon occurrence—she would here probably encounter waves 18 feet high and 500 feet long, having a period of 10 seconds; and instead of beating backwards and forwards under reefed topsails and foresail, losing ground every tack, and perhaps by an unlucky shift of wind finding herself embayed and unable to save herself from being driven on shore, our wave-power ship would be able to put her head to it like a steamer, having actually in such a sea 600 horse-power at her command, which would enable her to go ahead in the teeth of the gale and secure a good offing.

Supposing after she had got into the open ocean and the weather moderated, but with the wind still ahead, she would be almost certain of waves say 9 feet high and 10 seconds period, in which case she would have 300 horse-power, which would enable her to go ahead at the rate of $7\frac{3}{4}$ knots; or, if the waves were say 6 feet high, she would have 200 horse-power, and would go ahead at the rate of about $6\frac{3}{4}$ knots, this would be instead of beating to windward, and making at the best 2 knots per hour to windward. When she gets into the north-east trade, she might secure her revolving weight and proceed under canvas. When within 4 or 5 degrees of the Line she would enter the belt of calms, a space usually about 300 miles wide, and in crossing which ships often spend a fortnight, and seldom do it in less than a week. In this region there is a long glassy swell about 3 feet high and 10 seconds period.

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Mr. Deverell, in his voyage home in the *Norfolk*, observed the height of the swell in the belt of calms to be as much as 4 feet, he having had the opportunity of observing this point accurately from a boat; and I can speak from my own experience that this swell exists, though I have never measured the height, but supposing we say 3 feet, for that height just gives our ship 100 horse-power, when the wave motion is in the same plane as the revolving weight—and I am supposing that the weight is mounted to revolve in a fore-and-aft plane, so that we should only get this result with the sea exactly aft or ahead; with the sea abeam, in which case only the vertical oscillations would be utilized—we should get just 50 horse-power. Suppose on the average we got 75 horse-power, with which she would proceed at $4\frac{3}{4}$ knots per hour, which would carry her through the calms in about two and a half days, she would then pick up the south-east trade, which would carry her to about 25 degrees south, when she would have westerly winds which might do well enough for her till she came to double Cape Horn. She would here realise the full benefit of her machinery, which would probably be working up to 600 horse-power until she got well round, and would be certain to materially shorten a passage which sometimes takes ships as long as two months.

Probably in the whole voyage the machinery would be working say forty days, and indicating on an average up to 200 horse-power. To do this with steam, with the best engines, would cost about 200 tons of coals, and with the saving of which the wave machine would have to be credited.

What is possible in theory *may* be possible in practice, and if I have convinced you by this Paper that this scheme is correct in theory and desirable in practice, I shall have attained the object for which I have come before you to-night.

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DISCUSSION.

Mr. WILLIAM FROUDE, F.R.S.: I should like to say a very few words upon this Paper, because Mr. Tower has mentioned my name as having witnessed most of his experiments. I wish to say, that the whole subject is a very obscure one, and very difficult to explain shortly and clearly to an audience in *vivâ voce*. I can only say, that I feel quite sure of the veracity of Mr. Tower's statement as to the quantitative results he has attained, as they are given in the Paper, and I think I thoroughly see the dynamical principle on which he proceeds. Mr. Tower has in fact opened out a new line of thought with reference to the power to be deduced from wave motion. It is true, weights of 100 tons, revolving through a space of 40 feet, and so on, at once involve formidable considerations; but it will be a very great gain if he has—and any mathematician, I think, will on reading his Paper see that he has—succeeded in showing that the operations of the waves are such as to yield power on the scale, and in the particular manner his Paper points out.

Dr. J. WOOLLEY, F.R.A.S.: Your Lordship will allow me to say one word. We all know that the only difference in which the force of waves differs from that of water at rest is in the addition of the centrifugal force; and it appears, from what I understand of Mr. Tower's explanation, that this apparatus which he has invented is really one in which he actually applies to the best possible purpose that can be conceived the full effect of the centrifugal force—that force, in fact, which is really and virtually the destructive wave force. I think we must all agree with what has fallen from Mr. Froude, that Mr. Tower has demonstrated the fact,—that force, and an available force, can be obtained in this way. But, of course, the practical application of it is a different thing; and it would be a very important matter if Mr. Tower could point out to us how it is to be applied, although, in his Paper, he says he will not enter into the question of how this is to be effected ultimately by machinery. Yet, as he seems to propose that some such machinery should be fitted to ships which now usually navigate the seas under sail alone, it would be desirable if he would give us some idea of what space such machinery would take, in order to obtain the horse-power which he says would be available, because it depends very much upon that what the practical value of his invention would be for the purpose of merchant vessels.

Mr. JOHN SCOTT RUSSELL, F.R.S.: The only part of this Paper as to which I have any doubt is the mode of making the practical application of it. The part on which I have no doubt whatever is this: As we understand the mechanism of these secondary or oscillating waves, there can be no doubt whatever that the motion of one of these waves consists of the two elements of which the writer of this Paper has spoken. One of those elements is the back-and-forward motion, which back-and-forward motion can be, through any other means, converted into another back-and-forward motion; and, as energy is given out and absorbed in each of these back-and-forward motions, it is quite plain that by concentrating that energy in a solid body moving round a centre, he can turn that energy into direct mechanical power. It is also true that, in the same waves, there is a rising-and-falling motion equal in amount to the fore-and-aft motion, those two motions, the rising-and-falling and the fore-and-aft motion, can both be utilized by a properly placed mass of matter. Whether that properly placed mass of matter can be made a convenient engine propeller—whether the weight of 100 tons, 40 feet high above the bottom of the ship, can be made a comfortable uniform propeller, and whether the waves will always come to the end of the ship exactly when they are wanted, and not at another time, is a question of practice, which I will

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not discourage, but, on the contrary, would encourage the writer of this Paper to examine into very closely. What I say is, that, from my long familiarity with the waves, he has thoroughly understood their general nature, and that they do possess this intrinsic force; and if he has invented a convenient manner of utilizing them, all I can say is that he has done a very clever thing.

The PRESIDENT: As a practical question I think there can be no doubt that the views that have been expressed in this Paper by Mr. Tower are both important and very difficult, and that he has treated them in a very able manner. I am sure that he is at least entitled to our best thanks for the Paper which he has read.

Mr. B. TOWER: I should like to make one observation with reference to Dr. Woolley's enquiry about the general proportions. I have a model here which is supposed to be a model of the imaginary ship, which I mentioned in my Paper, of 1,100 tons displacement. It has on it machinery to produce wave motion. The waves are generated by an india-rubber web, which is stretched upon cranks, and I think anybody who has seen waves at all will admit that this is a very good representation of what waves are like, and that it goes a long way to prove that the theory of each particle in a wave revolving in a circle is a correct one. I have described in my Paper a method that is possible for regulating the motion of the weight by causing the pumps which it drives to act as an engine, by an apparatus for regulating that action, and thereby accelerating the weight when necessary to make it keep time with the waves.

The PRESIDENT: The next Paper is on "Notes on Polar Diagrams of Stability," &c., by Mr. Mac Farlane Gray; but there being some difficulty with regard to that Paper being read, it must be taken as read, and does not admit of any Discussion.

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ON POLAR DIAGRAMS OF STABILITY.*

By J. MAC FARLANE GRAY, Esq., Chief Examiner of Engineers, Marine Department, Board of Trade, Member.

[Read at the Sixteenth Session of the Institution of Naval Architects, 18th March, 1875; the Right Hon. LORD HAMPTON, G.C.B., D.C.L., President, in the Chair.]

IN the *Transactions* of the Institution for 1871 there are two excellent Papers treating of diagrams of stability, one by Mr. Barnaby and one by Messrs. White and John. It may be that a perusal of those interesting Papers has left in my mind the following methods in embryo, as the development of one from the other seems to me to be almost a matter of course. As, however, I have not seen them described in any publication, perhaps they will be accepted as a not uninteresting extension of the graphic treatment of the problem of stability already so well discussed in those Papers.

If O Q S U (Fig. 1, Plate IV.) be the curve of the loci of the centres of buoyancy for a certain vessel, and P *a* a normal to that curve at the point P, and O *h* a perpendicular on P *a* through the point O, then O *h* is the righting arm, or arm of the stability couple, for the inclination corresponding to the point P. If in like manner the successive normals be all intersected by perpendiculars drawn through the fixed point O, the loci of these points of intersection will form a curve O *h b k m l*, which is a polar diagram of stability for the centre of gravity at the point O.

It would be of little use to refer to the construction of this curve if it applied only when the point which has been taken as its origin is the centre of gravity. The remarkable property of being easily converted into a stability diagram for any other position of the centre of gravity, gives it the value that has led me to represent some of its applications in this Paper.

To draw the stability curves in circular arcs, find the centres of the approximating or oscular arcs of the buoyancy curve, *a b c d e f* (Fig. 1), and draw the radial lines,

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a O, *b* P, &c., at the junctions of these arcs, that is, join *a b* and produce to P, join *b c* and produce to O, &c. The point O, the origin of the stability curve, may be taken in any position, either within the buoyancy curve or outside of it, and not necessarily on the central line as in Fig. 1. Join O *a*, O *b*, O *c*, &c. Bisect these lines in 1, 2, 3, &c. From 1, as a centre with radius 1 O, describe the arc O *h*, cutting *a* P in *h*. From 2, as a centre with radius 2 O = 2 *h*, describe the arc *h k*, cutting *b* Q in *k*. From 3, as a centre with radius 3 O = 3 *k*, describe the arc *k l*, cutting R *c* in *l*.

Proceed in the same manner with the others, taking the centres in the order of the corresponding arcs in the buoyancy curve, stopping each arc at an intersection with its corresponding radial line, *viz.:* the arc from centre 1 at an intersection with the radial line (or normal to the curve of centres of buoyancy) through *b* and so on. These arcs if continued will cut the radial lines in two points, at one of these the ordinate through O is perpendicular to the radial line, and that is the intersection which is to be taken as the termination of the arc. If the successive radii are taken to the point O, *viz.:* 1 O, 2 O, &c., the succeeding arc will not join unless the proper intersection has been taken, and this checks the construction.

The complete curve drawn as directed is a polar diagram of stability for the centre of gravity at O, the origin of the curve. As the curve of centres of buoyancy is fixed with regard to the vessel, it follows that the radii vectores or ordinates of the stability curve are to be read as the directions of inclined water-lines. That reading of the curve is indicated by the skeleton hulls shown on the curves; the shading marks the side of the hull that is immersed, and the inclination of the water-line is the direction of the radius vector, or line drawn through O.

When the origin of the curve is taken at a point in the buoyancy curve as O, the complete stability diagram forms two closed curves intersecting at O. The stability arm changes its sign at that intersection, the effort of gravity being exerted always at a right angle to the radius vector, as if acting on the radius vector as a lever with the force applied at O, the position of the centre of gravity, acting downwards with respect to the water-level shown on the skeleton hull.

In Fig. 2, one of these curves is again delineated showing the heeling of the vessel from the upright towards starboard 180°, that is capsizing by heeling to starboard. In using the word starboard, I suppose the right-hand side of the diagrams to be starboard. When the origin of the stability curve is a point within the buoyancy curve, it becomes a curve of four branches with the origin a multiple point. For illustration only, such a curve is represented in Fig. 2 for the centre of gravity at the point C, which point is the origin of the curve of four loops, which is a stability diagram for that centre of gravity.

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The centres of curvature were found in Fig. 1 by bisecting O *a*, O *b*, &c.; now they are found by bisecting C *a*, C *b*, &c., in the same order, and terminating the arcs at their intersections with the same lines as before.

It is not necessary to construct such looped curves, because a stability diagram for any point as origin is at once converted into a stability diagram for any other position of the centre of gravity, by merely describing a circle on the line joining these two points, as O *r* C *u* described on the diameter O C. The stability arms are then *p q*, *r s*, *t u*, &c., the heeling action being as if the force were applied to the arm at its point of intersection with the circle passing through the centre of gravity. In Fig. 2, *p q*, *r s*, tend to turn the hull to port, and *t u* tends to turn it to starboard. The point *v* is, therefore, evidently a point of stable equilibrium, and at that point the arms change sign.

If this simpler diagram be compared with that formed with the four loops, it will be found to agree with it exactly. It is obvious that the segment of a radius vector from C between its intersections with the curve about C, and with the circle through C and O, is in like manner the stability arm for the centre of gravity at the point O.

The usefulness of this diagram is impaired by the acuteness of the angles at the intersections near the upright position. At an inclination of 90°, however, the intersections are nearly at right angles, and if we could transfer this quality to the neighbourhood of the upright position, we would have the sharp definition where it is more required in a stability diagram.

In Fig. 3, on the left, stability diagrams are drawn as described for the prism whose transverse section is given. The stability curves are all for the centre of gravity at the point O, and for the three displacements indicated by the three water levels shown.

It may seem a ridiculous position for the centre of gravity, so far to one side, but that is only a device to get a curve that will give definite intersections at moderate inclinations. For the centre of gravity at the point E, describe a circle on O E as diameter, *viz.*, O F E A G. That circle and the stability curve for the immersion form a stability diagram. At the immersion *c* the righting arm at 40° inclination is F B. In this figure the skeleton hulls are shown on an arbitrary circle of degrees, and the sense in which the arm acts does not apply to them as given above except when they are shown on the stability curve itself, as in Figs. 1 and 2. The direction of turning is thus,—the portion of the radius vector, which represents the righting arm, turns upon the point of its intersection with the stability curve in the direction that moves the point of its intersection with the circle *down* with reference to the water level shown on the

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skeleton hull. At 40°, therefore, the arm F B is a *righting* arm. At 160° G H is a capsizing arm. The arm does not change sign in passing the point O. At 80° the arm acts to turn the hull to starboard, and the action at 110° is in the same sense.

In Fig. 3, on the right, I have shown another method of representing the stability of a vessel; it is not mathematically exact, but it is practically an accurate approximation. About the centre, C, a point in the vertical centre line, an arc of 90° is described through a point A, the nearly lowest position in which the centre of gravity can be placed. The righting arms for the centre of gravity at A, and for a given immersion, are set off on radial ordinates, this gives the stability curve for that immersion, and for any position of the centre of gravity. The stability diagram for any position of the centre of gravity E, and the same immersion, is completed by describing an arc *with the same radius* through K and E. The arc, having the same radius in every case, can be cut out of cardboard and so applied to the two points K and E.

The two curves shown are for the water levels *a* and *c*. It is obvious that the first part of the curve from K is a portion of an arc that would pass through the principal metacentre for the given immersion, and that its radius is equal to C K. It is also obvious that the height of the point L is determined by the position of the horizontal normal of the curve of centre of buoyancy.

My object in writing this Paper is to present practicable methods of constructing stability diagrams that might be adopted by naval architects, and drawn upon the midship-section in the plans furnished to the owner to be a guide in stowage, and a help in settling freeboard. The prismatic method of delineating curves of buoyancy explained in Mr. Barnaby's Paper, if used with a pentagon section, would be sufficiently accurate for every practical purpose.

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ON A MODULUS FOR STRENGTH OF SHIPS.*

By J. MAC FARLANE GRAY, Esq., Chief Examiner of Engineers, Marine Department, Board of Trade, Member.

[Read at the Sixteenth Session of the Institution of Naval Architects, 18th March, 1875; the Right Hon. LORD HAMPTON, G.C.B., D.C.L., President, in the Chair.]

I HAVE for some time been advocating the adoption of a standard modulus of strength for comparing different ships. According to the system of calculation now adopted, the strength per square inch, when on a certain wave, is the modulus used. The height of the wave is, however, to a great extent, an arbitrary assumption, and when the resulting moment is taken as equivalent to the weight of the ship, acting with a leverage equal to a certain arbitrary proportion of the length, we are introducing a constant factor which may readily mislead, but can never assist when comparing different ships. If, however, the modulus of strength be taken as the strain per square inch produced by the weight of the ship, acting with a leverage equal to the length of the ship, on a girder having a section the same as that of the vessel, the number representing the strain in tons will be free from arbitrary factors, and must be the same for the same section, whatever may be the opinions of the calculator as to the height of the wave. It is that number I now recommend to be used as a standard modulus of strength of construction of iron vessels.

In large vessels the number found as above is sometimes as high as 250 tons for tension, and 150 tons for compression; and I propose that the character of the vessel, so far as is indicated by these numbers, should be represented as modulus $\frac{250}{150}$, the upper number referring to tension on the upper member of the girder, and the lower number referring to compression on the lower member.

These numbers can be readily reduced to strain in tons per square inch on a wave, supposing the moment of strain to be equal to the product of the displacement in tons

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by a certain fraction of the length of the vessel, the same fraction of the number has to be taken as the strain. As one person may assume $\frac{1}{35}$th of the length as about the effective arm, while another may take $\frac{1}{20}$th, the strain will be $\frac{250}{35} = 7\frac{1}{7}$ tons, or $\frac{250}{20} = 12\frac{1}{2}$ tons for the same ship, whereas if the number for comparison be left as 250, the same vessel will always have the same modulus whoever calculates it.

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ON COMPOUND ENGINES.*

By R. Sennett, Esq., Fellow of the Royal School of Naval Architecture and Marine Engineering, and Instructor in Marine Engineering, Royal Naval College, Greenwich, Member.

[Read at the Sixteenth Session of the Institution of Naval Architects, 18th March, 1875; the Right Hon. Lord Hampton, G.C.B., D.C.L., President, in the Chair.]

The question as to the relative merits of simple and compound engines, especially for ships of war, is one that has for a lengthened period occupied the attention of the engineering world, and although much ability and ingenuity have been displayed in condemnation of the compound engine, the fact remains that its use is rapidly extending, and we seldom hear of any new steam ship not fitted with compound engines, whilst many ships with simple engines have had them compounded and high-pressure boilers fitted.

This question is of so much importance that it should be considered from all points of view, and every possible light thrown on it; and I propose, therefore, in this Paper to call attention to a few facts that tend to make the compound engine more economical than the simple expansive engine; and by comparing two engines working to the same power, with the same pressure and expansion of steam—one being a simple engine and the other compound—to show that the advantages claimed for the compound engine are not fictitious.

The Admiralty Committee on Designs of Ships of War were entirely in favour of the compound engine, and in their Report they say:—"The carrying power of ships "may certainly be to some extent increased by the adoption of compound engines in "Her Majesty's service. Its use has recently become very general in the mercantile "marine, and the weight of evidence in favour of the large economy of fuel thereby "gained is to our minds overwhelming and conclusive. We beg, therefore, earnestly "to recommend that the use of compound engines may be generally adopted in ships "of war hereafter to be constructed; and applied, whenever it can be done with due "regard to economy and to the convenience of the service, to those already built."

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This Report was made after receiving the evidence of six of the leading marine engineering firms in the country, from superintending engineers of three of the principal Steam Navigation Companies, and after a Report had been written on the subject by Professor Rankine.

Professor Rankine, in his remarks, enters very fully into the laws of expansion of steam, and the conditions necessary to make the expansion effective. There is one paragraph in his article which I think contains the gist of the whole matter. He says:—"So far as the theoretical action of the steam on the piston is concerned "it is immaterial whether the expansion take place in one cylinder or in two or more "successive cylinders. The advantage of employing the compound engine is connected "with those causes that make the actual indicated work of steam fall short of its "theoretical amount; and also with the strength of the engine and its framing, the "steadiness of its action, and the friction of its mechanism."

The first part of the paragraph requires, perhaps, a little modification; for, in most compound engines, the *theoretical* action of the steam is not so perfect as in simple engines, owing to the resistance of the ports and passages between the cylinders, and in many cases to the loss by sudden expansion on the admission to the reservoir. Notwithstanding this, the mass of evidence from steam-users—who, after all, are the men most qualified to judge—is in favour of the use of compound engines; and we must consequently turn to the other points mentioned, as those on which the superiority of the compound engine lies.

When steam does work by expansion, the quantity of heat extracted from it is sufficient, not only to lower the temperature of the steam to that corresponding to its lowered pressure, but also to cause a portion of it to liquefy. When the communication to the condenser is opened, and the pressure falls to the condenser pressure, the interior surfaces of the cylinder, cylinder cover and piston, which may be supposed to be of an intermediate temperature to that of the entering steam and that of the condenser, give out heat to the water condensed on them, which causes the water to re-evaporate; thus increasing the back pressure and sending a quantity of heat direct to the condenser, without having performed any useful work. In the same way the action of these surfaces on the entering steam deprives it of some of its heat, and, consequently, lowers its pressure. The great loss from liquefaction is, therefore, due to the fact that it acts as an equaliser of temperature; lowering the initial, and increasing the final temperatures and pressures, and thus decreasing the efficiency of the steam.

There can be little doubt that liquefaction, which is one of the principal causes that make the actual indicated work of steam fall short of its theoretical amount, is much

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more injurious in simple engines, with high rates of expansion, than it is in compound engines. The liquefaction due to the work done would, of course, be the same in the two cases; but the difference of temperature between the entering steam and the sides of the cylinder in the case of the simple expansive engine is much greater than in the compound engine; and consequently, from the laws of radiation and conduction of heat, we may infer that the reduction of the initial pressure and the increase of the back pressure in the case of the simple engine would be greater than in the compound engine.

We will now consider the balance of forces on the shaft; and, in order to illustrate this point, we will take two engines, one simple and the other compound, working to the same power with the same pressure and expansion of steam, and draw diagrams representing the twisting moments on the shafts.

Suppose the diameters of the cylinders of the compound engine to be 57 inches and 95 inches respectively. Since the simple engine is to have the same capacity for expansion as the compound engine, its two cylinders must be together equal to the low-pressure cylinder of the compound engine, and the diameter of each will, therefore, be about 67 inches. The stroke in each case is taken at 2 feet 9 inches, the length of connecting rod 5 feet 6 inches, the speed of piston 500 feet per minute, the pressure of steam in the boilers 60 pounds per square inch, and the total rate of expansion 8.

Fig. 1 (Plate V.) gives the diagrams that might be expected from the compound engine, the lengths of the diagrams being made proportional to the volumes of the cylinders so as to show the efficiency of the expansion. The outline of the combined diagrams in Fig. 1 may be taken to represent the theoretical diagram from the simple engine, no allowance being made for the lowering of the initial or the increase of the back pressure due to the liquefaction.

Fig. 2 is the diagram representing the twisting moments on the crank-shaft of the compound engine, and Fig. 3 the corresponding diagram for the simple engine. The dotted curves represent the twisting moments for each cylinder separately, and the full curves the combined twisting moments. The mean twisting moment in each case is 725 inch-tons. The maximum moment in the case of the compound engine is 1,030 inch-tons, giving a ratio of maximum to mean of 1·42 to 1. In the case of the simple engine the maximum twisting moment is 1,300 inch-tons, giving a ratio of maximum to mean of 1·793 to 1.

This is, however, without taking into consideration the inertia of the reciprocating parts of the engines, which play a most important part in the pressures on the crank pin at the different points of the stroke. The indicator diagram simply gives the pressures of the steam on the *piston* throughout the stroke, and though the *total* pressure

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on the piston throughout the stroke will, excepting a little loss by friction, be equal to the total pressure on the crank pin throughout the stroke, yet the *distribution* of the pressures during the stroke will be very different.

To the indicator diagram must be added another diagram, representing the work done in moving the reciprocating parts of the engines. At the beginning of each stroke the motion of the reciprocating parts receives acceleration; and, consequently, the pressure that causes this acceleration must be deducted from the pressure shown by the indicator diagram, in order to get the pressure acting on the crank pin. The amount of acceleration gradually diminishes till about the middle of the stroke, when the velocity of the piston is for an instant uniform, and the acceleration becomes zero; then retardation begins, and the work that was expended in acceleration is again given out, and the pressure on the crank pin is thus increased beyond that shown on the indicator diagram to the same extent that it was before diminished.

Fig. 4 is the diagram of twisting moments on the crank-shaft of the compound engine when allowance is made for the inertia of the reciprocating parts. The maximum twisting moment is reduced to 960 inch-tons, and the ratio of the maximum to the mean is 1·32 to 1.

Fig. 5 is the corresponding diagram for the simple engine, and shows a somewhat curious result. It will be seen that although the maximum twisting moment due to *each* cylinder is considerably reduced, yet, owing to the equality of weights of reciprocating parts in each cylinder, the increase at the end of each stroke nearly counterbalances the decrease at the beginning, and the *combined* diagram is almost identical with the diagram when the inertia of the reciprocating parts was neglected; the maximum moment being 1,250 inch-tons, and the ratio of the maximum to the mean being 1·724 to 1. This slight reduction is simply due to the difference of motion of the piston at the opposite ends of the stroke, resulting from the obliquity of the connecting rod. Had the connecting rods been of infinite length the motion of the piston at each end of the stroke would have been the same, and then the diagrams would have been exactly identical in the two cases, the inertia of the reciprocating parts producing no effect on the combined diagram of twisting moments.

In this case, therefore, we find that the maximum twisting moment on the shaft of the simple expansive engine is more than 30 per cent. greater than that on the shaft of the compound engine. In consequence of the greater uniformity of twisting moment the shafting and framing may be made lighter in the compound than in the simple expansive engine, and much greater steadiness of motion may be obtained, and more efficient action of the propeller in the water expected.

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For convenience of reference the results from the two engines are shown in the following Table.

	Compound Engine.	Simple Engine.
Cylinders ... ... No.	2	2
„ diameter	57 in. / 95 in.	67
Length of stroke	2 ft. 9 in.	2 ft. 9 in.
Length of connecting rod	5 ft. 6 in.	5 ft. 6 in.
Speed of piston in feet per minute ...	500	500
Total ratio of expansion	8	8
Indicated horse-power	2,100	2,100
Mean twisting moment on shaft in inch-tons	725	725
Maximum twisting moment neglecting inertia of reciprocating parts	1,030	1,300
Ratio of maximum to mean ...	1·42 to 1	1·793 to 1
Maximum twisting moment including inertia of moving parts ...	960	1,250
Ratio of maximum to mean	1·32 to 1	1·724 to 1

The great variations of pressure in the case of the simple engine would probably also have a tendency to produce the same effect on the shaft that vibration does—that is, to cause the structure to become crystalline.

Some years ago four ships for a German Steamship Company were fitted by Messrs. Caird & Co., of Greenock, with simple engines, working at a high rate of expansion, the working pressure of steam in the boilers at sea being from 60 to 70 pounds per square inch. The thrust-shafts of each of the four vessels broke at sea after a comparatively short period of service, and this was considered to result from the intermittent excessive strains brought on the shafting. The tonnage of the ships was about 2,500, and the indicated horse-power, when at sea, 1,500 to 1,600.

I may also add that very recently an engineering firm on the Clyde declined to tender for the supply of simple expansive engines, working with high-pressure steam, on the ground of the danger to the shafting and framing incurred by this method of working.

One advantage claimed for the simple engine for war ships is, that on going into action the steam pressure might be reduced, for safety, without so great a loss of

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efficiency as in the compound engine. I think that this is more imaginary than real; for if this line of argument were carried to its logical conclusion, we should find ourselves back to the engines and boilers in use forty or fifty years ago, which worked at the atmospheric pressure or a little above. If, however, this point were insisted on, it would be very easy to adapt the compound engine for this purpose by simply fitting connections between the high-pressure cylinder and the condenser, and between the low-pressure cylinder and the steam pipe, to be used in cases of emergency. I do not think, however, that the tendency of engineering is to return to the low-pressures in use forty or fifty years ago, but on the contrary that the pressures will be increased considerably beyond that at present in use, and the expansive force of the steam more fully developed. If the pressures and rates of expansion be increased, it appears from the diagrams of twisting moments given, that regarding the strains on the shafting and framing alone, the compound engine is the only type that can be safely employed, and we shall have to provide against the casualties of action, not by working with steam at or about atmospheric pressure, but by thoroughly protecting the vital parts of the ship, of which the region of the engine and boiler rooms are not the least important, and by *sub-division of the engine and boiler rooms* into separate compartments, so as to reduce the chances of disaster to a minimum.

I will now call attention to the results of a few comparative trials that have been made to test the relative economy of the two systems based on the amount of water used per indicated horse-power per hour.

The first experiments we will consider, were made on the U. S. survey vessel *Bache*, by Mr. Charles Emery, of New York, and the results were published in *Engineering* of January 1st, 1875.

The *Bache* had a compound engine, with the small cylinder arranged above the large cylinder, the two pistons having a common rod. Direct steam communication was fitted to the large cylinder, so that it could be worked independently, using steam of the same pressure and with the same degree of expansion as when both cylinders were working together as a compound engine. This connection was originally designed for use in case of accident to the high-pressure cylinder.

The large cylinder was steam jacketed, and experiments were made both with and without the jacket in use.

We shall confine our attention to the experiments made with the jacket in use, and shall select examples of simple and compound expansion as nearly approaching each other as possible. The particulars are given in the Table on next page.

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On reference to the Table, it will be seen that in each case the consumption of water per indicated horse-power per hour was considerably less in the compound than in the simple expansive engine. From columns 1 and 4 we see that with a ratio of expansion of between five and six times, the water used per indicated horse-power per hour was in the simple expansive engine 23·15 pounds, whilst in the compound engine it was only 20·36 pounds, showing in this case a gain in economy by the use of the compound engine of rather over 12 per cent. At the higher ratios of expansion the per-centage of economy was still greater.

The consumption of water for the power developed was both in the compound and in the non-compound engine much greater at the high rates of expansion, shown in columns 3 and 6, than at the lower rates. The non-compound engine was not tried at a higher rate of expansion than 12·62 times, whilst the compound engine was worked at 16·85 times. By increasing the rate of expansion in the simple engine from 8·57 to 12·62 times the consumption of water per indicated horse-power per hour was increased from 24·088 pounds to 27·113 pounds. It is evident from this, that had an expansion of 16 or 17 times been carried out in the simple engine, the water used per indicated horse-power would have been considerably over 30 pounds per hour.

		COMPOUND.			SIMPLE EXPANSION.			
		1	2	3	4	5	6	7
1	Duration of trial ... hrs.	1·983	2·066	1·733	2·116	1·683	2·10	1·883
2	Pressure of steam in boilers ... ... lbs.	80·125	80·333	80·375	79·5	81·071	80·833	30·875
3	Ratio of expansion ...	5·732	9·19	16·85	5·11	8·57	12·62	2·18
4	Vacuum in condenser ins.	26·56	26·5	24·5	25·52	25·29	24·66	24·0
5	Revolutions per minute	56·34	48·18	38·87	53·84	46·25	39·92	45·28
6	Indicated horse-power ...	110·5	77·5	46·4	116·0	74·6	54·8	66·7
7	Water per indicated horse-power per hour by measurement ... lbs.	20·36	20·71	25·11	23·15	24·09	27·11	34·03
8	Water per indicated horse-power per hour from indicator diagrams ... ... lbs.	15·25	15·76	18·53	16·25	15·58	16·42	24·04
9	Proportion of water used accounted for by indicator diagrams	·749	·761	·738	·702	·647	·606	·707

It must not be assumed, however, because the consumption of water for the power

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developed is greater at very high rates of expansion than at lower rates, that it is never beneficial to use these high rates.

Engines of war ships on ordinary service are generally working at considerably reduced powers, and it is a question of some importance whether in such cases it would be wiser to reduce the pressure in the boilers, and work at a low rate of expansion, or to keep up the pressure of steam and use a higher rate of expansion.

A comparison of columns 5, 6, and 7 of the Table would appear to show that the latter plan is the correct one. Column 7 gives the results of working the engine with reduced steam pressure when only low powers are required. It will be seen that whilst in the trial given in column 5 the water used was only 24 pounds, and in column 6 27 pounds per indicated horse-power per hour, the water used on the experiment shown in column 7 was 34 pounds per indicated horse-power per hour, the horse-power in this experiment being between those given in columns 5 and 6.

These experiments show that a high rate of expansion can be carried out more economically in the compound than in the simple expansion engine. There are practical difficulties in the way of carrying out high rates of expansion in simple engines that must not be lost sight of. For example, in the cases of the engines referred to in the former part of this Paper, it will be seen that in the compound engine steam is carried in the high-pressure cylinder when working at full power for 14 or 15 inches, so that there is plenty of range for the expansion valve to be used when working at low power, and the pressure of steam in the boilers may be kept at or near the maximum. In the simple expansion engine the steam is only carried for a distance of 4 or 5 inches in the cylinder when working at full power, so that the practical range of expansive working is much reduced, and when the engines are required to work at low powers, either the pressure of steam in the boilers must be reduced or the steam must be throttled, so that the benefits of high pressure and expansion are to a great extent lost.

It would therefore appear that at reduced speeds the compound engine would in general be more economical than the simple expansive engine. This is of no small importance when we consider that it is only on comparatively rare occasions that ships of war have to steam at full speed, and that for by far the greater period of their service they are steaming at speeds varying from 4 to 7 knots an hour.

There is another point that should be referred to in connection with these experiments. Line 9 of the Table gives the proportion of the total quantity of water used that is accounted for by the indicator diagram. The nearer this approaches unity the less will be the loss from condensation in the cylinder, jackets, &c.

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It will be seen that in the compound engine the proportion of water accounted for by the indicator diagram was about the same at each rate of expansion, whilst on referring to columns 4, 5 and 6, we find that in the simple expansive engine the proportion diminishes as the rate of expansion is increased, being ·702 when the rate of expansion was 5·11 times, and ·606 when the rate of expansion was increased to 12·62 times. In each case, too, the amount of water accounted for by the indicator diagram of the simple engine was less than that in the compound.

The only comparative trials of the two systems that have, as yet, been made in the Royal Navy were those on the two gunboats *Goshawk* and *Swinger*, of 360 indicated horse-power, and these were very limited in extent. The engines of the *Goshawk* were made by Messrs. Maudslay, Sons & Field, and are of the compound type, with cylinders 28 inches and 48 inches diameter, and a stroke of 1 foot 6 inches. The engines of the *Swinger* were made by Messrs. Humphrys and Tennant; they are simple expansive engines, with two cylinders of 34 inches diameter, and length of stroke 1 foot 10 inches. The boilers in each ship are similar, the safety valves in each case being loaded to 60 pounds per square inch.

The total weight of the *Goshawk's* machinery is 75¼ tons; that of the *Swinger* is 75¾ tons; so that, notwithstanding the addition of the high-pressure cylinder, the compound type of engine is not necessarily heavier than the simple expansive engine.

The ships were each tried for six hours, at a 6-knot speed, and the performance, as measured by the *estimated* quantity of coal burnt, was slightly in favour of the simple engine; the coal used per indicated horse-power per hour in the *Swinger* being, apparently, 2·073 pounds, and in the *Goshawk* 2·142 pounds. On the 25th May, 1872, both ships were tried for six hours, at full power, when the performance, judged simply by the coal account, was again slightly in favour of the simple engine; the consumption per indicated horse-power per hour in the *Swinger* being given as 2·60 pounds, and in the *Goshawk* 2·61 pounds.

When we come to compare the indicator diagrams, however, we find quite a different result. On the 6-knot trials the amount of water used per indicated horse-power per hour, as measured from the indicator diagrams taken, was in the *Swinger* 21·47 pounds, whilst in the *Goshawk* it was only 18·69 pounds. Again, on the full-power trial, of 25th May, 1872, the water used per indicated horse-power per hour in the *Goshawk*, as measured from the indicator diagrams, was only 15·57 pounds, against 21·32 pounds in the *Swinger*.

On reference to the trials of the *Bache*, before quoted, we see that a larger proportion of the total quantity of water used is accounted for by the indicator diagram

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in compound than in simple engines; so that this comparison shows more favourably for the simple engine than would probably have been the case had the actual quantities of water used been measured.

A great deal of stress has been laid on the fact that the consumption of coal per indicated horse-power per hour given for the *Swinger* was rather less than that given for the *Goshawk*. I think, however, it will be admitted that such a basis of comparison is misleading, and is quite unsuitable for scientific purposes. It is impossible to estimate accurately by the eye the quantities of coal on the stokehole plates and in the fires at the commencement and conclusion of the trial. On the correctness of this estimate, however, depends the reliability of any comparison made with the quantity of coal burnt as a basis, and it is very evident that in any short trial of from four to six hours there is such a margin of possible error that the coal burnt per indicated horse-power cannot be taken as affording a satisfactory basis of comparison. The only absolutely true method is to ascertain by actual measurement the exact quantity of water used. In the *Goshawk* and *Swinger* this was not done, so I have taken the quantity of water used as shown by the indicator diagram as being the nearest approach to the truth.

For convenience of reference some particulars of the performances of the *Goshawk* and *Swinger* are shown in the following Table:—

	Goshawk.				*Swinger.*			
	Full-Power Trials.			6-knot Trial.	Full-Power Trials.			6-knot Trial.
Date of trial ...	7 Feb.,'73	28 July,'73	25 May,'72	6 Feb.,'73	11 June,'73	17 Oct.,'73	25 May,'72	12 June,'73
Indicated horse-power	481	484	376	77·8	461	525	365	80·4
Speed of piston ... ft.	402	401·4	378	220	454	470	425	233
Weight of steam used per hour lbs.	7,896	8,184	5,852	1,454	9,100	11,022	7,781	1,726
Weight of steam used per indicated horse-power measured from indicator diagrams ... lbs.	16·42	16·91	15·57	18·69	19·74	21·0	21·32	21·47
Coal used per indicated horse-power per hour as estimated ... lbs.	...	...	2·61	2·142			2·60	2·073

It is probable that before the close of the year we may have more data on which

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comparisons of the economical working of the two systems may be based. There are at present in course of construction for the Admiralty two pairs of simple expansive engines of 360 indicated horse-power, and two pairs of 900 indicated horse-power; the pressure of steam in each case being 60 pounds per square inch.

The results of the trials of these engines, compared with those of the compound engines in the other ships of the same classes, cannot fail to be of great importance, and will no doubt do much to determine which type of engine is most economical,—and, all things considered, which is the most suitable for ships of war.

DISCUSSION.

Mr. John Scott Russell, F.R.S.: I beg to say that I think this is an admirable Paper. I think it, first of all, admirable for its accuracy, and still more for its rare moderation, because you find that most engineers are whole-hog advocates of the other system, and each gives to his favourite all the good qualities and none of the bad. The writer of this Paper has touched admirably upon the real merits of the case, which are these. There is no advantage, in a general way, between the development of steam in one cylinder and the development of steam in two successive cylinders. But there are great inconveniences in certain results arising from the single cylinder which we have not yet generally found the means of correcting. For example, as was well touched upon by the author, in single-acting engines you put into one end of a very large cylinder steam of intense pressure, and you work that out in the same large cylinder to steam of very small, or if you can, little or no pressure. That is a perfect single-acting engine and you then have the best possible, but you have put yourself into a most awkward position by the first stroke for the second stroke; because when you make the second stroke with the engine, though the first was admirable, the second consists of letting in very hot steam in large quantities into the end of a cylinder which has practically become a condenser, which is very cold and which is probably covered with chilled cold water. There is a practical evil—I do not go into the quantity of the evil, but in the development of steam there is no advantage in a couple of cylinders. The first advantage in a couple of cylinders is that you have one cylinder into which you only put very hot steam, and another cylinder into which the steam goes and becomes cold. You certainly have the power of expanding the steam in the very hot cylinder to a degree without much loss, and then you expand it to the remainder in the large cylinder with also not much loss, and then at the end of that time you arrive at pretty nearly the same result, with this great difference—that when you make the second stroke the hot steam comes into the hot cylinder, and when you make the second half of the second stroke this steam goes into the cold cylinder, so that the cold goes to the cold, and the hot goes to the hot, and the loss from the hot going direct to the cold is not there. That is one advantage. Another great advantage upon which the author of the Paper laid the proper value is this. On letting on high pressure steam in a single large cylinder, it goes in with such a terrible thump that the whole engine quivers. From the marvellous experiments of Mr. Eaton Hodgkinson, it was shown that a given bit of iron would only bear a certain number of thumps, and when it had got that number of thumps, the virtue died out of it, and it was no longer good iron. Mr. Eaton

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Hodgkinson having taught us that when we overstrained a bit of iron we used up a bit of its life, and put ourselves in great danger. The first thump of the hot steam going into the big cylinder strikes like a hammer on the piston rod, upon the connecting rod, upon the cranks, and upon the shaft, and it very soon uses up the life of the bits of iron of which these machines are made in our large engines, and so these bits of the engines very quickly become feeble, and die of consumption. The irregularities are beautifully shown in the capital diagrams which have been made to illustrate this subject, and the practical result is that the compound engines, being durable trustworthy engines, going comparatively smoothly, and not injuring the materials of which they are made, have become deserved favourites, notwithstanding that in their structure they cost a great deal more money, that in their management they require a good deal more attention, and in the abstract they do not give out much more power. But there is just a sufficiency of advantages on all points to have turned the practical opinion of the great majority, I think, of practical engine makers, who have experience of both sorts, decidedly in favour of the compound engine.

Mr. J. Fortescue Flannery: There are just one or two points in connection with this subject that I should like to call attention to. The author of the Paper has shown us distinctly and clearly (and his view has been supported by Mr. Scott Russell) that the maximum crank effort is very much more irregular with the simple expansive engine than with the compound engine, and that is shown in an extremely graphic manner by the diagram. As has been said, such unusual efforts, and such a jerky motion upon the piston rod and other moving parts of the engine, have a deteriorating effect upon the iron. But there is another, and as it appears to me, almost as important a disadvantage attending this sudden expansion, and irregular motion of the shaft, which is this—that, as the screw is revolving, by the jerky motion that takes place a much larger per-centage of slip at particular periods of the revolutions takes place than at others; and then there is a jerky backward motion of the water imparted, and a corresponding loss of power in propelling the ship forward, which is the result of an unequal crank effort, which is not the case where the shaft goes round uniformly. The other point is this—that the expansion of steam can be more easily accomplished by two cylinders in an old engine than by a single cylinder; that is to say, unfortunately valve gear wears; and, as the author of the Paper mentioned, a simple engine having the same degree of expansion would require to be cut off at about 4 inches of the stroke, whereas in the compound engine having the same ratio of expansion it would cut off about 15 inches of the stroke. There we see the great difference in the portion of the stroke the valves would cut off. That being so, it is evident that, in the case of an old engine whose valves are worn, or whose valve gear is at all deranged, the original designed ratio of expansion would be interfered with in the case of a single engine more than in the case of a compound engine; and when we deal with particular engines, as we must do, knowing that engines wear out, we shall have to take that matter into consideration. I mention those two things because they have not been touched upon by other speakers.

Mr. J. Scott Russell: I omitted to mention that there is also great loss in the single engine from the extreme variation of the pressure on the bearing surfaces.

The President: It only remains for us to express our thanks to Mr. Sennett for the clear and able Paper which he has read to us, and I have to express my regret that I am afraid it will be impossible for me, on account of other business engagements, to attend here to-morrow morning. I hope therefore that one of my friends, one of the Vice-Presidents, will be kind enough to relieve me to-morrow. To-morrow evening, at 7 o'clock, I shall be very happy again to be with you.

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ON THE DUTIES, QUALITIES, AND STRUCTURE OF THE MODERN MAN-OF-WAR.*

By JOHN SCOTT RUSSELL, Esq., F.R.S., Vice-President.

[Read at the Sixteenth Session of the Institution of Naval Architects, 19th March, 1875; JOSEPH WOOLLEY, Esq., LL.D., F.R.A.S., Vice-President, in the Chair.]

ON a subject so important to England as her fleet of men-of-war, it may be deemed useful and patriotic that a Meeting like ours should contribute, from time to time, some of its thought, technical knowledge and practical experience to the consideration of what we as a nation have been doing to create and maintain a fleet, and what we should next do in order to provide the fleet of the future, keeping carefully in mind the essential point of a fleet and the first condition of its value, *viz.*, that its purpose is not merely to fight a battle, nor to lose a battle, but to win certain victory.

Our periodic meetings are peculiarly favourable to such large views and such wide national considerations. We come here once a year, from all the seaports of England, bringing with us great variety of experience and great diversity of views. We meet here sailors and shipbuilders, naval officers and naval constructors, of our own and of other countries. We can, therefore, have the matter thoroughly discussed through a wide range of thought and knowledge.

I propose merely to open this large and important discussion by a sketch of what we have been doing, and an estimate of what we should do, in the hope of eliciting from the Members a more thorough investigation of the subject than I shall attempt.

The year 1875 is particularly suited to this discussion, because it happens to mark an eventful period. We had one revolution in the great question of the fleet of the future in 1855, at the end of the Crimean War. We had then to create a fleet of iron-clads, and we had got one ready by 1865, but it was composed mainly of our wooden men-of-war, lengthened, supplied with steam, and coated with the armour suited to the

* Received 19th March, 1875.

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guns of the time. We had also created a new fleet of six iron-clads, entirely of iron, also with central batteries defended by armour, known as the *Warrior* class. Since 1865 we have profited by the experience of naval war in America and at Lissa, and have learned from them two great lessons:—That fast unarmoured ships can protect or destroy the most valuable commerce of the ocean, by chasing and sinking merchant fleets; that a small ship, with one great gun, well protected by turret or shield, can destroy a fleet of the best bygone men-of-war, however large, however well manned, and however many her guns; that one strong fast ship, well protected and well commanded, and skilfully built, and skilfully manœuvred, can sink a ship and disperse a fleet, without firing a gun, by that new tactic, concisely called "giving the stem," or simply running down.

Let us then, now, consider what we have been doing during the last ten years to give ourselves a fleet, not merely able to fight, but certain of victory. Have we a fleet able to chase from the seas all the fast ships which our enemies will send out to destroy our commerce by sinking our merchant ships? Have we a fleet of fast iron-armoured men-of-war, sufficiently armed to penetrate the ships of our enemy—sufficiently protected to resist his guns—sufficiently fast to choose our own time and place for the fight—sufficiently buoyant to carry fuel and stores into any ocean where we require their service, and to engage and defeat the enemy in his own waters, instead of in ours? Have we, for the defence of our own shores, harbours, bays, and seas, a fleet of multitudinous, but smaller ships, themselves unsinkable, but able to penetrate the largest ships by one or two of the largest shot, at the highest velocity—which means greatest penetrating power—and able also to pierce and destroy the largest of the enemy's ships by a single shot, or by stem on and running down? Have we a large reserve of floating batteries, all ready to be towed to their stations, for defending our rivers, ports, and havens, the moment the alarm of war is given? Have we a multitude of small fast gunboats, each forming in itself a great gun carriage—each moving with great rapidity—ready to swarm out around any large ships or fleet that may threaten any of our dockyards or our fortresses, or our commercial ports?

If we have all these quite ready and equipped and manned, with plenty of ammunition and well-trained crews and officers on board—and plenty more waiting on shore anxious, ready, and fit to take their place—that would be a most fortunate conclusion to our discussion, should we be happy enough to attain it.

Whether plans of our fleets of the future have been wisely prepared—whether the ships, their guns, their equipment, their crews, and their organization are all quite ready for immediate action, and only waiting for the occasion for their use—is a question

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more for the Government of the country than for our Meeting. We saw, in the late Continental war, how much can be done in a very short time by a Government which keeps every thing quite ready for immediate action. Let us hope that, in naval warfare, our own is wise and perfectly prepared. Our narrower and professional question is this: Can we, by any wisdom of our own, from our technical knowledge and practical experience, contribute anything towards the improvement of the fleet of the future?

The first class of ships deserving our attention is the modern man-of-war. I will start, for my present purpose, by a comparison of our present needs with the conditions of the earliest class of these ships—the *Warrior* class. Are ships of this sort of any value now? What change should they undergo?

In my opinion the *Warrior* class is still, in some respects, an excellent type of a modern man-of-war. (1*st.*) She is fast. (2*nd.*) She is a good sea boat. (3*rd.*) She has a powerful battery. (4*th.*) She is fit for a long voyage, and carries abundant stores and fuel. On the other hand, her armour plating was made for the guns of her time, and is penetrable by modern guns. Therefore, the thickness of her armour wants increase—the size of her guns wants increase—this increased weight wants increased beam, power, and displacement, not increased length. The principle of a central battery, first shown in the *Warrior* design, may be considered as established.. The increasing weight of gun and shot and armour only tends to limit the extent of the battery, and to limit the number of the protected guns; but I think the principle of the *Warrior* class, *viz.*, central battery, with magazine, engines, and boilers all under protection, continues to be expedient and practicable. We may take the *Sultan*, *Monarch* and the *Audacious* class as the nearest approach to types of this advanced *Warrior* class, in 1875.

But, while the experience of the past has not disproved or diminished our confidence in the usefulness of this largest class of man-of-war, for long voyages and long war, and large concentrated and combined actions, I think that our belief in the utility of multiplying the smaller classes of ships increases. The dangers of a large ship, from shells, from torpedoes, from penetration, and running down, are very great, and growing greater.

I will now, therefore, ask you to consider a war vessel from the opposite point of view. Let us ask ourselves what is the smallest vessel fit for modern warfare.

My personal opinion and experience have grown steadily towards the conviction that we should consider a modern war vessel as a mere tool or instrument of destruction, not a ship in the eyes of the sailor: quite unworthy of the name; a mere floating gun carriage—a mere floating spear, propelled by steam, and meant, first, to place an explosive shell in the enemy; and, second, to run into his side and sink him. If I am

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right in supposing that what I say truly represents modern naval opinion, then we come to a very simple practical conclusion. Let us take one big gun, let us give it the largest bore, the largest shell, the highest penetrating speed we now know. Let the vessel herself be considered in the light merely of a floating gun carriage. Let this one large gun occupy the chief place in the vessel in front of her engines and boilers and propellers. Let it be as small a ship as is consistent with high speed; let it be propelled by high-engine power; let it show very little above water; and let it have a short ugly stem to strike the enemy and sink him.

Not only high speed, but admirable dexterity and quickness of movement or manœuvring are indispensable to this sort of vessel; she must be low in the water—nearly unsinkable—all her decks perfectly closed—waves must break over her without harm; she must be steady, quick, and sure.

It may be said that such a ship is hard to find, and hard to make, and hard to handle. Certainly she is hard to work; but is not all great noble work hard, and are not victories always hard to win?

If you agree with me in regarding this one-gun boat as the type of an effective instrument of naval destruction, the next question which naturally arises is this, when we want two guns, shall we have a two-gun boat, or two one-gun boats? The arguments on this point are the following:—In many practical cases of experience we find it prudent to have duplicates;—we may have two pumps where one would do; we may have two cylinders where one would do; two screws where one would do; two boilers where one would do. My answer is, that duplicates are useful in little things; we cannot afford them in principals, though we can in subordinate things. My personal opinion is that two large guns in two small gunboats are better than two large guns in one small gunboat. To this rule, however, I know of exceptions in these two cases—the large many-gunned man-of-war, with central battery and central armour coating, and the small single great gunner. I have taken extremes, because I think both of these inevitable and indispensable to England. There is a third fleet of indispensables—I mean the cruiser. She must be an ocean steamer—a large, long, fast, large gunned, many gunned, long ranged, steady, easy, good sea boat, carrying large store of coal, and other stores. She must have great destructive power, great endurance, great manœuvring power, and with high speed, power to choose her own enemy, and her own time and place and manner of action. Only she cannot be covered with armour. Also, she can, if not absolutely secured, be comparatively well protected by certain precautions, which may be well considered. Let us consider these. Let us put all that wants protection well under water; let us give protection by armour, if necessary, in small

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quantity near the midway water-line; let the whole of the ship above the water be thin iron, quite unprotected; let the whole ship be in cellular water-tight divisions, of convenient, and even somewhat inconvenient smallness, but judiciously arranged, so as to be conveniently accessible for good, and conveniently inaccessible for harm. By these and many similar precautions, which I will not here enumerate, the ocean cruiser may be made the queen of the seas.

Here, then, are three classes of ships or fleets, about which we need be in no doubt as part of the fleet of the future:—

1.—*The Man-of-War.*—Large, fast, enduring, many and large guns, central battery perfectly shot proof, engines, boilers, and magazine perfectly protected; possessing, also, all the protecting precautions of the cruiser, but slower and heavier; enduring; a hard hitter, and hard to hit.

Have we a fleet of these? How many have we?—want we?

2.—*The Single Great Gun Boat.*—Long, narrow, low, fast, quick, clever, ugly and sharp, unsinkable. Of these we want, not a mere fleet, but a multitude, not numbers, but swarms, clouds.

Have we swarms of these?

3.—*The Many Large-Gunned Ocean Cruiser.*—Long, wide, deep-sided, fast, enduring, quick in her manœuvring, with destructive power, and small protection, able to do great harm and ready to run great risks.

Have we fleets of these ready for each of the oceans in which we have Colonies, and are certain to have war?

[TABLE.

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Table I.—English Fleet of 1865.—Iron Armour.

(Reproduced from Mr. John Scott Russell's "Modern System of Naval Architecture.")

Class.	Name of Ship.	Length between Perpendiculars.	Breadth, Extreme.	Tonnage, O.M.	Height of Ports.	Guns. Number Protected.	Guns. Number Pierced for.	Length of Battery.	Thickness of Armour Plates.	Thickness of Backing.	Thickness of Skin behind Armour.	Horse-power. Nominal.	Horse-power. Indicated.	Draught of Water. Forward.	Draught of Water. Aft.	Displacement.	Speed.	Cost. Hull.	Cost. Engines.	Cost. Total.	Remarks.
		ft. in.	ft. in.	tons.	ft. in.			ft.	in.	in.	in.			ft. in.	ft. in.	tons.	knots.	£	£	£	
Frigates.																					
Iron *Warrior* Class.	*Warrior* ...	380 2	58 4	6,109	9 4	26	40	213	4½	18	9/16	1,250	5,469	25 6	26 5	8,852	14·35	286,285	74,710	360,995	Battery on one deck. Designed under Sir Baldwin Walker by Mr. I. Watts, late Chief Constructor of the Navy, in conjunction with Mr. John Scott Russell.
	Black Prince ...	380 2	58 4	6,109	8 6	26	40	213	4½	18	9/16	1,250	5,772	26 4	27 3	9,300	13·6	288,911	74,902	363,813	
	Achilles	380 0	58 3½	6,121	8 10½	26	40	213	4½	18	9/16	1,250	5,743	25 10	27 2	9,400	14½	388,219	69,591	457,810	
	Minotaur ...	400 0	59 3½	6,621	8 10	26	44	385	5½	10	9/16	1,350	5,722	25 10	26 10	10,200	14·33	349,322	76,036	425,358	
	Northumberland	400 0	59 3½	6,621	8 10	26	44	385	5½	10	9/16	1,350	6,621	25 10	26 10	10,200	15·46	216,259	67,900	284,159	
	Agincourt ...	400 0	59 3½	6,621	8 10	26	44	385	5½	10	9/16	1,350	6,867	25 10	26 10	10,200	15·43	343,547	80,137	423,684	
Wood *Caledonia* Class.	*Caledonia* ...	273 0	59 2	4,125	6 9	30	36	280	4½	30	...	1,000	4,092	23 6	26 9	5,800	13	242,375	52,183	294,558	Designed by Mr. I. Watts.
	Royal Oak ...	273 0	58 6	4,056	7 2½	35	36	280	4½	30	...	800	3,704	23 8	25 8	6,416	12½	214,080	45,365	259,445	
	Prince Consort	273 0	58 5	4,045	7 2½	31	36	280	4½	30	...	1,000	4,234	23 8	25 8	9,430	13	196,423	52,783	249,206	
	Ocean	273 0	58 5	4,047	6 9	23	36	280	4½	30	...	1,000	4,244	23 6	26 9	6,535	13	223,898	52,152	276,050	
	Royal Alfred ...	273 0	58 5	4,068	7 1½	14	18	165	6	30	...	800	3,434	24 0	25 6	6,400	12.36	199,158	44,752	243,904	
	Lord Clyde ...	280 0	58 9	4,067	8 6	24	40	280	4½ & 5½	31½	2	1,000	6,064	24 6	26 0	7,675	13·43	221,400	57,000	278,400	Designed by Mr. E. J. Reed, late Chief Constructor of the Navy.
	Lord Warden	280 0	58 9	4,067	8 6	24	40	280	4½ & 5½	31½	2	1,000	6,706	24 6	26 0	7,675	13·5	221,400	64,000	285,400	
	Zealous ...	252 0	58 7	3,716	7 8	16	20	103	4½	30½	...	800	3,623	24 6	26 0	6,027	11·71	180,990	51,146	232,136	
Iron *Resistance* Class.	*Hector*	280 0	56 5	4,089	7 2½	20	32	288	4½	18	9/16	800	3,256	24 0	25 7	6,960	12½	242,395	45,753	288,148	Designed by the Admiralty.
	Valiant	280 0	56 3	4,063	7 4	24	32	288	4½	18	9/16	800	3,560	25 10	26 10	6,420	11½	263,258	48,609	311,867	
	Resistance ...	280 0	54 1	3,710	7 6	14	18	143	4½	18	9/16	600	2,428	23 9	26 0	5,986	11½	213,889	33,785	247,672	
	Defence	280 0	54 2	3,720	7 7½	14	18	143	4½	18	9/16	600	2,537	24 3	25 6	5,971	11¾	206,783	34,385	241,168	
Corvettes.																					
Iron *Bellerophon* Class.	*Bellerophon* ...	300 0	56 0	4,246	9 6	12	16	110	6	10	1½	1,000	6,312	21 0	26 0	7,053	14·05	212,380	72,500	284,820	Designed by Mr. E. J. Reed, late Chief Constructor of the Navy.
	Hercules	325 0	59 0½	5,234	...	10	14	...	3 to 9	12	...	1,200	7,187	22 6	26 6	8,702	13·8	320,000	81,000	401,000	
Turret Ships	*Royal Sovereign*	240 7	62 2	3,765	5 8	5	5	246	5½	36	...	800	2,463	21 6	25 0	5,000	11	146,236	53,604	199,840	The late Captain Cowper Coles' Turret system.
	Prince Albert ...	240 0	48 0	2,529	7 0	4	4	245	4½	18	½	500	2,128	20 0	20 0	4,020	11·65	147,776	22,464	170,240	
Wood partial Battery Ships.	*Pallas*	225 0	50 0	2,372	7 6	6	6	50	4½	22	...	600	3,606	18 3	24 3	3,688	13·05	97,745	38,400	136,145	Designed by Mr. E. J. Reed, late Chief Constructor of the Navy.
	Favourite ...	225 0	46 9	2,094	9 0	8	10	66	4½	26	...	400	1,773	19 3	22 3	3,116	11·83	123,130	23,921	147,051	
	Research ...	195 0	38 6	1,200	6 0	4	4	34	4½	19½	...	200	974	12 9	15 3	1,780	10½	64,077	10,364	74,441	
	Enterprise ...	180 0	36 0	990	6 7½	4	4	34	4½	19½	...	160	710	13 3	15 6	1,370	10	54,456	8,693	63,149	
Sloops.																					
Iron-turret Ships.	*Scorpion* ...	220 3	42 4	1,857	...	4	4	225	4½ & 3	9	...	350	1,455	14 11	16 4	...	10·52	...	...	109,746	Hull and machinery designed and constructed by Messrs. Laird. The *Wivern* is fitted with tripod masts, on the system of the late Captain Cowper Coles, R.N.
	Wivern	220 3	42 4	1,857	...	4	4	225	4½ & 3	9	...	350	1,446	14 8	16 1	...	10·06	...	...	113,760	
Gunboat Class.																					
Iron.	*Viper*	160 0	32 0	737	6 10	2	4	59	4½	10	½	160	696	9 6	10 6	1,070	9·59	42,287	7,611	49,898	Designed by Mr. E. J. Reed, late Chief Constructor of the Navy.
	Vixen	160 0	32 5	737	6 10	2	4	59	4½	10	½	160	658	9 9	10 9	1,020	9·06	46,331	7,869	54,200	
	Waterwitch ...	162 0	32 0	777	6 10	2	4	60	4½	10	½	167	777	10 0	10 0	1,170	9·24	43,080	13,642	56,722	This ship is adapted from the *Viper* by Admiral Elliott.

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Table II.—English Fleet of 1875.

Class.	Name of Ship.	Length between Perpendiculars.	Breadth, Extreme.	Guns. Number Protected.	Thickness of Armour Plates.	Thickness of Backing.	Horse-power. Nominal.	Horse-power. Indicated.	Draught of Water. Forward.	Draught of Water. Aft.	Displacement.	Speed.	Cost. Hull.	Cost. Engines.	Cost. Total.
		ft. in.	ft. in.		in.	in.			ft. in.	ft. in.	tons.	knots.	£	£	£
Turret Ship ...	*Inflexible* ...	320 0	75 0	4	24 to 16	17 to 25	...	8,000	23 0	25 0	11,165	14·0	350,000	...	...
"	*Dreadnought* late *Fury*	320 0	63 10	4	14 to 10	18 to 15	...	8,000	26 6	27 0	10,886	14·0	350,000	107,000	457,000
" ...	*Thunderer* ...	285 0	62 3	4	14 & 12	18 to 16	800	5,600	26 2	26 3	9,157	...	245,000	46,500	291,500
" ...	*Devastation*	285 0	62 3	4	14 & 12	18 to 16	800	6,649	26 2	26 3	9,157	13·8	245,000	46,500	291,500
Central Battery	*Alexandra* ...	325 0	63 8	12	12	12 to 10	...	8,000	26 0	26 6	9,492	14·0	311,000	108,000	418,500
With Barbette Towers ...	*Temeraire* ...	285 0	62 0	8	11	12 to 10	...	7,000	26 6	27 0	8,412	14·0	281,000	...	...
Turret	*Rupert*	250 0	53 0	4	14 to 9	14 to 10	700	4,200	21 6	23 6	5,358	13·6	189,600	38,500	228,100
"	*Shannon* ...	260 0	54 0	9	9	10 & 12	...	3,500	22 0	22 6	5,103	13·0	168,000	...	...
Broadside ...	*Sultan*	325 0	59 0	12	9 to 6	12 to 10	1,200	8,629	24 10	27 6	9,286	14·13	281,300	76,000	357,300
Turret ...	*Monarch* ...	330 0	57 6	7	10 & 8	12	1,100	7,842	22 7	26 0	8,322	14·9	280,000	74,700	354,700
Central Battery	*Swiftsure* ...	280 0	55 0	10	8 to 6	10	800	4,913	24 1	26 2	6,660	13·75	207,000	49,000	256,000
"	*Triumph* ...	280 0	55 0	10	8 to 6	10	800	4,892	24 2	26 2	6,660	14·07	207,000	49,000	256,000
"	*Audacious* ...	280 0	54 0	10	8 to 6	10	800	4,021	22 0	23 0	6,034	12·8	190,000	52,000	242,000
"	*Invincible* ...	280 0	54 0	10	8 to 6	10	800	4,832	22 0	23 0	6,034	14·09	190,000	52,000	242,000
"	*Iron Duke* ...	280 0	54 0	10	8 to 6	10	800	4,268	22 0	23 0	6,034	13·6	190,000	52,000	242,000
"	*Vanguard* ...	280 0	54 0	10	8 to 6	10	800	5,312	22 0	23 0	6,034	14·07	190,000	52,000	242,000
Broadside ...	*Repulse* ...	252 0	59 1	12	6 & 4½	side 31 in. thk	800	3,347	25 4	26 2	6,190	12·28	156,200	27,400	183,600
Turret	*Glatton* ...	245 0	54 0	2	14 to 12	18 to 20	500	2,868	19 0	19 0	4,912	12·1	189,000	30,400	219,400
Ram	*Hotspur* ...	235 0	50 0	1	11 to 8	15 to 12	600	3,497	19 0	20 8	4,010	12·65	135,000	36,500	171,500
Broadside ...	*Penelope* ...	260 0	50 0	8	6 & 5	10 & 11	600	4,703	15 9	17 4	4,394	12·76	146,000	41,000	187,000
Turret Ships	*Cyclops* ...	225 0	45 0	4	6 to 10	11 to 9	250	1,660	16 5	16 5	3,430	11·03	135,000	16,000	151,000
	Gorgon ...	225 0	45 0	4	6 to 10	11 to 9	250	1,670	16 5	16 5	3,430	11·14	135,000	16,000	151,000
	Hecate ...	225 0	45 0	4	6 to 10	11 to 9	250	1,755	16 5	16 5	3,430	10·9	135,000	16,000	151,000
	Hydra ...	225 0	45 0	4	6 to 10	11 to 9	250	1,472	16 5	16 5	3,430	11·2	135,000	16,000	151,000

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ON THE REQUISITES OF NEW NAVAL GUNS AND GUN CARRIAGES.*

By John Scott Russell, Esq., F.R.S., Vice-President.

[Read at the Sixteenth Session of the Institution of Naval Architects, 19th March, 1875; Joseph Woolley, Esq., LL.D., F.R.A.S., Vice-President, in the Chair.]

Naval guns, gunners and gunnery, differ in so many essentials from military men and weapons in their aims, means, and mode of use, that their structure, circumstances, and appendages should be widely different. What is good for one may be folly for the other.

On land artillery in England we have expended enormous sums of money on new guns, which we now all admit to be worthless and dangerous. But we have gained, at great cost to the nation, knowledge which we should now use for the public good.

Before we began our new experiments on gunnery we possessed one gun which was possibly the best in the world: it was our 68-pounder 95-cwt. gun. Both Army and Navy had unlimited and well-earned confidence in that gun. Its power of endurance was enormous; the initial velocity which it gave to the shot was greater than most of our modern guns; it was both durable and efficient.

Since then we have gone on a false track, and have paid a large penalty; this false track has done most harm in failing to give us trustworthy and efficient durable naval guns. For the design of the best naval gun, we should try to throw aside the prejudices and traditions of the past, and look the absolute facts of the case full in the face as they now stand. For the work of the future man-of-war, what do we want the ship's guns to do? Formerly, what we wanted to do, was to kill the enemy's crew, and make them haul down their flag, and therefore to board their ship. What do you want now? You want to destroy the ship, not the men. You want either to blow her up or run her down, that is all: the small objects and small injuries of the past have no value now. To destroy a large ship is our modern aim, and that our modern man-of-war must do or

* Received 19th March, 1875.

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fail. Two means alone can destroy large ships—large shells, or running down. The soldier fights with the bullet or the bayonet. The ship fights with the shell or the stem. Now, this view of the case imperatively demands guns of great bore. Pray mark the difference—I do not say guns of great weight merely, I say guns of great bore. In this distinction I am marking the cause of our great blunders. We have been wasting our time and means on guns of great weight and small bore, when we should have been making guns of great bore, and should have been expending our means and brains on making our great-bore guns as slight, strong, handy, and effective as possible. That should have been our aim; that must be our future aim; if not for military guns, at least, for naval guns. Starting, then, from our old naval great gun of 95 cwt. and 8 inches bore, as the naval gun of the past, what should we have taken as the gun of the future? To this I answer directly, I should at once have taken a bore of 12 inches.

To this you reply, at once, that 12 inches is a bore requiring an enormous weight of gun. I reply, that is the radical mistake; a great bore does not require a great weight of gun, a small bore does require a great weight.

To explain this, I must point out another blunder of the past. We used to fancy that the bore of a gun was intimately bound up with the weight of the shot. That was true. It is so no longer. With the old-fashioned gunnery the weight of the spherical shot was exactly measured by the bore of the gun; with rifled shot and shell these trammels have entirely disappeared. You are left entirely free to choose the weight of your shot, independent of the bore of your gun.

When I say that for a gun of given weight—say 12 or 18 tons weight—I prefer a bore of 12 inches for a naval gun to a bore of 8 inches with that weight, at least for naval purposes, I must state another special point we want in a naval gun. You have been present, I have no doubt, as I have been, at many of our experiments on the power of guns to penetrate ships' armour, and on the power of armour to resist penetration. You have seen it proved there, as I have, that the destructive and penetrating power of the shot is due, not to the mere weight of the shot so much as to its high speed. You know by theory also, as well as by experience, that penetrating or destructive power is proportioned not merely to the speed, but to the square of the speed. Thus you know that with a shot at 1,000 feet a second, and another at 1,400 feet a second, the latter has double the penetrating power, though it has scarcely a half more speed, whereas to have equal effect by weight it would require double weight. While again, double speed would give four times the penetrating power.

This shows you why in ship destruction we want high speed of shot above

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everything. This is why I select a large bore of gun instead of a little bore, to give me a high speed of shot and shell, or penetrating power.

I have next to show why and how I get a high speed better from a great-bore gun than from a small-bore gun. For hitherto we have acted on the contrary maxim, and got a greater speed by a smaller bore.

Here also we encounter a radical change of principle, which I beg to recommend to your close attention. It is quite true that on a small scale smaller bore guns give higher speed to shot. But this is untrue on the large scale. In ships you already know that what is true for one size and speed is false for another size or another speed, so also is it in guns. What is true in small guns may be false in great guns. It is neglect or ignorance of this and such like principles that has led us astray.

The change of conditions on going from a small-bore gun to a large are these:—

1.—On the small scale, the strength of the metal of the gun is far beyond the strength needed for the strain of the powder. On the large scale the useful strength of the metal falls off rapidly as the size grows.

2.—On the small scale, the proportion of weight of shot to area of bore is very small. On the large scale, it becomes destructively great.

3.—On the small scale, the whole strength of the whole gun is effectual in resisting injury to the gun itself. On the large scale, only a small proportion of the whole metal of the whole gun gives effectual aid to prevent the ruin of the gun itself; and thus the forces we prepare to ruin the enemy only injure our own guns and gunners. I remember standing near one of our great guns when it burst. The occasion was to me most instructive. It satisfied me that only a very small portion of this great costly new gun of wrought iron and steel was of the slightest use in strengthening the gun.

In illustration of the principles, I will now take given guns of larger and less bore, of equal weights, and loaded with shot of equal weight, and thus prove to you that the great bore is the good naval gun and the small bore is the bad one.

I first start with the old 8-inch gun. We will take as our question this,—We propose a substitute for it as a rifled gun. We know that our old spherical shot weighed 68 pounds. We want our new shot to weigh 240 pounds. Now, I ask the question practically. We agree that we may go in weight as far as 12 tons or 240 cwt. in our new gun. The practical question I mean to put is this,—Is it better to make our new naval gun of 12 tons, of the bore of 8½ inches, or of the bore of 12 inches?

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First compare those areas of bore:—

8½-inch bore contains 72 round inches	. .	(1)
12-inch bore contains 144 round inches	. .	(2)

From this you conclude that, equal weights of shot being taken, it will only require half the force to gain equal speed of shot for given weight, or only one half the bursting force per inch of gun.

Or if you take equal propelling force per inch, the same shot that leaves the small bore with 1,000 feet initial speed will leave the larger bore with 1,400 feet initial speed.

Coming now to the main point of endurance of the gun and its safety, I say that for the same speed of the same shot the gun is only strained one half in the great bore of what it is in the little.

So much for the gain of speed. You see that the gain is unquestionable, and I now come to the question of strain on the metal.

It may be said that the 12-inch 12-ton gun is thinner than the 8½-inch 12-ton gun.

It is thinner, but only in the proportion of 15 to 13, while its work is more effectual in the ratio of 26 to 13.

But this is understated. You all know that the inner coating bears much more effectual strain than the second, and the third outwards bears still less. Now the difference between the small bore and the large bore in this respect is that the two inner effectual thirds remain in the large one, and only the least efficient of the three is removed. The less thickness of the large bore is therefore compensated further by its great efficiency.

I need not continue these details further. I believe you will be able to satisfy yourselves, as I have done by calculation and by trial, that in very large heavy guns the larger bore has a predominance of advantages, and the smaller a predominance of disadvantages.

I next pass to a question of shot and shell and charges for the great-bore naval gun.

I have assumed in all I have said that we shall know how to regulate the discharge of our powder power, so as to get out of it the greatest quantity of useful force with the least quantity of hurtful force.

I may say shortly how this can be got. Let the charges of our great-bore guns be made of large solid masses, not mere pebble powder, which is an error, but in properly proportioned hollow cylinders. In these let the lighting take place from the centre of the cylinder so that the powder burns uniformly outwards. This gives perfect burning,

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perfect efficiency, maximum useful effect; moreover, these cartridges, prepared in metal cases perfectly air-tight and water-tight, would be carried in a ship in the best possible condition both for general safety and immediate usefulness.

Lastly, as to shot, I call attention to the fact that since we gave up spherical shot and took to cylindrical shot, we have the power of making a far greater variety in the volume of the shot and shell, and in their dimensions and proportions than formerly. We can now fire with equal precision from a large-bore gun wide roving explosive shells and long, narrow, solid penetrating shot. The next point of importance to our guns at sea is a steady gun platform. This is to be given only by certain qualities of the ship.

This is to be obtained in the following manner:—(1.) By making the form of the ship such, that her stability shall be formed nearly equally of the three opposite kinds to which I beg your discriminating attention. (2.) Stability of form. (3.) Stability of weight. (4.) Stability of distribution.

Having got a ship with sea-going stability of gun platform, the next point is the gun carriage. Now I have little to say regarding the ordinary naval gun carriages, which have been fully studied and matured by most competent naval men. But I wish to say that there are very many cases in which the Moncrieff gun carriages offer the greatest advantages for naval great-bore gunnery. It is, however, only in special cases that their great value is manifest. All I wish to do is specially to direct the attention of naval men to them, as I clearly foresee that several classes of ships can do much better service if expressly designed for these gun carriages than if designed and constructed for the common one.

I feel sure you do not imagine that I mean to confine your plans of the future to the consideration only of the three great groups which appear to me to be the essentials of the fleet of the future. I have limited myself to them merely as the essentials to victory in the great ocean warfare of the future.

Besides these, there remain the special service classes of ships, which may serve as aids and supplements to our great fleets, and which require special adaptations to special aims for home service, while our large fleets must be ready to go into any ocean which requires their presence.

Turret ships are some of these; ships of exceptionally light draught and large guns are among these, floating batteries and despatch boats are others. And in general vessels built purely for what we call coast defence are what I call special service classes; I do not omit these because I undervalue them. I omit them because, even if we had any number of them, they would not enable us to gain a great naval victory on the open sea,

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nor to destroy the enemy's fleets in his own seas, and it is this form of attack which is our only sure defence of our country in the future.

I will, however, say a word or two that I think useful in regard to our special classes of ships. We want some classes of vessels for war, which shall be specially fit for service in rivers, bays, and shallows; fixed turret ships and revolving turret ships are among these. They must have light draught and large guns, and this special quality that they may pass by land fortifications without injury, and be able at one and the same time, while keeping their guns at work steadily on their enemy, to pursue their course steadily along a circuitous or winding channel. This service is to my mind the one service for which turret ships are specially suited.

For rivers, inland bays, and similar coast service, the important qualities are, light draught, handiness, large-bore guns, and high-speed shot; great endurance, long voyages, and sea-going qualities they may not have.

In regard to floating batteries, I have little to say, they will be easily destroyed by the single great gunners I have described. I must say that I am convinced of the great value of circular floating batteries, with thick armour and numerous great guns, made to revolve while firing by means of screw propellers, having also their propellers and engines so made as to be able to remove them from one place to another.

I am also in favour of large flotillas of extremely small shallow-water vessels, for pouring large heavy shells on to the decks of the enemy, if ever he should be rash enough to enter any English harbour among either our merchant fleets or our men-of-war. But I put them last on the list, because, as I have already said, our greatest wisdom lies in being ready to destroy on his own shores, in his own seas and harbours, the entire fleets of our enemy before he has time even to complete his arrangements for attempting to enter our seas. Everything short of this on our part would be mere childish folly.

I hope to have made it clear that while I give supreme importance to our ocean war fleets, I do not undervalue our home defence, and inland bay and river, and coast defence: I merely place it second.

In regard to all our classes of war ships, I wish to call attention to certain points of paramount importance, which I think it possible may not yet have acquired in the minds of younger men than myself all the attention and importance which my experience and observation, and my knowledge of the views of able men, have led me to attach to them.

1.—The proper proportion of ship, form of ship, and disposition of weights in a ship, which give that ship—in open sea, in heavy weather—a steady gentle wave motion; in other words, a steady gun platform.

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2.—The proper construction of ship, in regard to selection of materials of construction, and mode of construction, which shall give that ship endurance, not merely against the shot and shell of the enemy, but also against the heavy sea, and against shot and shell under water, by torpedoes or similar means, and also against running down.

3.—The proper mechanism of manœuvring the ship, so that with high speed and large dimensions your powerful ocean man-of-war and your ocean cruiser shall be as quick and handy in a heavy sea as an ordinary small ship in smooth water.

4.—The proper nature of the great gun of the future, and its shot and shell, and charge, and of its gun carriage, and its system of rifling, so as to get a maximum of destructive effect out of a given mass of gun and mass of ship, and material of attack and defence, and this with peculiar reference not to smooth water or stationary batteries, but specially to naval action on the high seas. In these respects a military battery and a naval battery are as different as possible—even contrary.

To those four points I call your special consideration. I have matured and decided views on them all; but it is plain that each is a subject of a special Paper, and there is not room here to exhaust any one of them.

DISCUSSION ON THE TWO PRECEDING PAPERS.

The CHAIRMAN: I am sorry to say that our President, Lord Hampton, is unable to be here this morning on account of important public business. He has deputed me to be his unworthy substitute in his absence. As we have a great deal of business to get through, I would ask the gentlemen present to assist me in carrying out the rules as far as we can, so that our Discussions may be kept within due bounds, but at the same time be as full as possible.

Mr. BELL GALLOWAY: As time is of importance I will not occupy beyond ten minutes. Unquestionably I agree with Mr. Scott Russell in the plans which he has produced, but in respect to the type of ship which is now before us (and I assume Mr. Scott Russell puts that type before us as a type of the ship of the future) I take leave most respectfully and submissively to his judgment to dissent therefrom. If you will allow me I will state in what particulars I dissent from it. You will observe that according to the history of the past, the requirements for a ship of war are speed, buoyancy, stability, and protectiveness, in order that she may become an effective fighting mechanical machine. In order to produce that we must have stability. Mr. Scott Russell says that he wants the stability just to be, in nautical phrase, so that the ship shall roll somewhat less than the action of the waves, but that she shall still roll. That is quite correct; but the type of ship which he has given us will not so completely answer that purpose as an alteration which I shall now propose will be calculated to do. You will observe that

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this form of vessel [*illustrating it*] with the keel not added, is a little short of the type we have now. Now all ships that partake of the oval egg, or cylindrical form, are sure to roll, and roll proportionately to the form of curvature. Now what we want is stability. Instead of putting a single keel, which would represent Mr. Scott Russell's design, I would reduce that ship to something like this [*illustrating it*], and I would have a single keel *here*, and a bilge keel *there*, and a bilge keel *there*. The effect of that arrangement would be that the ship would be more buoyant, that is to say, she would not draw so much water, and the column of water being confined between those keels would prevent the rolling, and therefore such a form of ship would give greater stability. We come now to the point which Mr. Scott Russell has suggested as to the working of guns, and I quite agree with him that it would be well to have guns so arranged that they would come down after being discharged. That is Sir William Armstrong's plan in a gunboat platform which he brought out. Now with respect to the plan proposed for the protectiveness of the ship, I quite agree that the ship should be so sheathed over the fighting decks that people's lives should be preserved. That is very easily done, and the whole arrangement, as described in the Paper, I thoroughly and entirely agree with, save and except so far as the formation and curvature in the bottom of the ship is concerned. All that has been said—and I am prepared to show it by plans and correspondence in my possession—in principle although not in detail, was submitted to the Admiralty in the years 1859, 1860, and 1861, and I propose to publish those plans and correspondence shortly, in order that it may be seen that the requirements which are now admitted to be absolute necessities, could have been applied, and were supplied long ago, and only required to be developed in order to prevent the complaints, lamentations, and discrepancies which have existed with regard to the Navy for the last ten years. Gentlemen, the plan you see before you here, so far as the formation and the bottom of the ship are concerned, I submitted to the Admiralty (and I can prove it) before the construction of the *Bellerophon*, and the *Bellerophon* was a *fac-simile*, to a certain extent, of that plan, with this difference, that the *Bellerophon* had the two keels put nearer. But the *Times* newspaper said—and I laughed in my own mind when I read it—that every one connected with nautical affairs would see that the fact of the columns of water being retained as between the keels on the bottom of the vessel, would give the vessel greater stability and render her more safe as a sea-going vessel. So far as the compartments of the vessel are concerned, I thoroughly agree. That is a subject to which I have devoted many years of my life; and if we want an efficient protective Navy, it will only arise from having ships of the nature and form which I have described, which will give the stability and every requirement necessary to inspire confidence in those who sail in them; and then, instead of having to pay men to fight the battles of our country, we shall have them coming forward and asking as a privilege to be allowed to fight.

Mr. F. J. Bramwell, F.R.S.: I will not occupy the Meeting even four minutes. Before the last speaker altered Mr. Scott Russell's diagram, I was glad to see in that diagram that which reminded me very much of the section of Wynan's cigar-ship. Mr. Scott Russell said, "I do not say a real cylinder;" but he made so nice a semicircle with continuations above the water-line that I feel content to take it as a portion of a circle.

Mr. J. Scott Russell: Say an ellipse if you will.

Mr. Bramwell: No, I would rather say circle. If I had had the sketch to make, with my limited knowledge of the laws which govern the rolling of vessels, and desired to get for the purpose of an easy

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floating gun carriage the minimum of motion, and that a regular motion, I should have been uncommonly inclined to have gone to Wynan's cigar-ship, a perfectly cylindrical form with the metacentre at or a little above the water-line, and the centre of gravity a little below it; and in that condition of things, as I know from experience of those vessels, you get the minimum of motion and the most regular motion. I think, therefore, the nearer the ellipse approaches the circle, the more nearly will Mr. Scott Russell's desire be attained, always supposing you are not going to press the ship over with canvas.

Admiral Sir ROBERT SPENCER ROBINSON, K.C.B., F.R.S.: I have listened with great interest to the remarks made by Mr. Scott Russell, in the two lectures or subjects on which he has discoursed. There is nothing that Mr. Scott Russell ever touches but what he ornaments. His facility of exposition is admirable, and the lucid manner in which he conveys an idea gives everything he ever thinks proper to handle the greatest possible charm in the ears of everybody who happens to listen to him. I think, myself, there were two very distinct subjects adverted to by Mr. Scott Russell; and I am only anxious, in the short time that I know is allowed to anybody to speak in this room, to advert to one subject which I think is the most important of all; and that is the subject on which Mr. Scott Russell first began to interest us. He has spoken more than once, to my great satisfaction and delight, about the necessity of method and forethought in the construction of the British Navy, and he has illustrated his positions by various arguments, more or less conclusive to those who will have, and upon whose shoulders now rest, the great *onus* and heavy work of constructing and maintaining the British fleet. Now all things are easy when you disregard the obstacles in the way, and if Mr. Scott Russell's plans, whether they are good or whether they are bad, could meet with a complete and thorough development, we should no doubt be in such a position as England has never held in this world before, and probably such as no other country ever held, or will hold; because Mr. Scott Russell puts before us all that is wanted in his own view, absolutely regardless of expense. Now, if we could bring Mr. Scott Russell face to face with every Member of the House of Commons, and if those eloquent axioms which we have listened to could be repeated and enforced upon obdurate and hard-fisted Chancellors of the Exchequer, and various Members of both the Tory and Liberal party, whom I have known in the course of my life, I should not despair, so highly do I value the rhetoric and eloquence of my honourable friend, that he might convince them that in this matter money was no object. I am most firmly convinced that it is our right and duty as a great power to be in such a position that we can make our voice heard, if we wish, in any corner of the world, in the tone we choose to adopt, which will always, I hope, be consistent with justice and moderation; and the essential point, in my opinion, to enable us to do that is to have a properly-constructed and powerful Navy. The great difficulty in the way of our obtaining such a Navy is the difficulty of money, and one great reason why it is difficult to obtain money which is wanted for the Navy is, that those who are charged with the responsibility of advocating the interests of the Navy in the House of Commons, Ministers of whatever character, or of whatever denomination they call themselves, whether they belong to the Liberal or the other party—are afraid to state clearly or deliberately to the House of Commons that the wants of the Navy are so large and so great, that larger estimates and more expenditure are required than the House of Commons likes to give, or the Ministers like to be responsible for. If that is the case now with the moderate new designs that are brought forward, small in number and only mere typical ships—ships that shall be types of other ships to follow—what chance has any Minister of being convinced, or if convinced, of putting his conviction into the shape of action, when he hears Mr. Scott Russell talk of the swarm of ships

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he requires, and says that those ships are to be ships of enormous magnitude, speed, and carrying power, with enormous guns and armour plating? I say when we have named even three or four of those qualities, every one must be perfectly aware that we are asking for something which is enormously expensive; and all the plans which Mr. Scott Russell has eloquently put before us, will, no doubt, resolve themselves into an expenditure which no House of Commons and no country can possibly submit to, or will by any chance give us under the present aspect of things. Whether it is wise or foolish—I think the latter—to sit with our arms folded and to trust we never shall be attacked, and that therefore a few ships are quite sufficient for our purpose and our wants, is another matter. My wish is to impress very strongly upon those who do me the favour of listening to my observations that the qualities of our ships of war should be what Mr. Scott Russell has described. We should have the most powerful armoured ships and the swiftest ships in the world. There were, and there have been, in the various forms of construction brought forward by the Admiralty constructors types of both those ships. I say that, for an armoured ship, the fastest ship that our Navy ever produced was built from a design that came from the Constructor's Department of the Admiralty—the *Inconstant*. She is a frigate of great power, with armour-piercing guns, with considerable qualities of sailing, and enormous speed under steam. That is a type of the fast ship which Mr. Scott Russell desires we should have, and which is exceedingly necessary for the purpose of chasing our enemy's cruisers off the face of the ocean, and for the protection of our commerce in every part of the world. We have not repeated those types of ships, but have left them alone; and if we have not repeated a ship which was so good ten or twelve years ago (for we have only one ship like her, which is now called the *Shah*) the fault does not lie with the naval constructors and naval designers, because they have been ready to repeat and improve upon those types of ships, and to produce ships of even superior excellence. The fault must be looked for elsewhere, and not in the Constructive Department, for not fulfilling the just expectations of the country. I am particularly anxious to say this, because I think it is exceedingly hard upon the naval architects and constructors, who have put together all the best ideas that are possibly available, and who have had most splendid success in realising what has passed through their minds, to find from some cause or another which, perhaps, had better not be adverted to, they cannot get their ships repeated, and are sent away with another design which is forced upon them in a manipulated shape, and not at all corresponding, except, perhaps, in one particular feature, to the ship they wish to have; and they are thereby made responsible for a Navy which is so incomplete as the list of ships before us points out,—showing, as it does, so many different types, and being as completely free, I must say, from any reasonable classification as it is possible to imagine. But for that I maintain that the naval architects and the naval constructors are not wholly responsible. Let me add one word more to illustrate what I have said. At the time of the construction of the *Devastation* no other ship of that class had ever been constructed with the same power of artillery and the same power of defence, and as for the stability and safety of the *Devastation*, the calculations which have been made and repeated over and over again prove on that point that in the *Devastation*, at any rate, we have got a ship of the most extraordinary power of armament, and the most extraordinary power of defence, and which is as remarkable for her handiness and swiftness as for her defensive and offensive powers. We had two of those ships at one time, and a third was got with considerable difficulty out of the superior authority that settles these matters. Now, what is the result? One of those ships is not completed, and will not be until the end of this year. The third of those ships, which was ordered to be constructed in 1870, cannot by any possibility be completed before 1877 or 1878. Now, I ask, is the naval architect or the

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Naval Constructor's Department responsible for those things? They are not. If the country wants to get an efficient Navy; if the country is not satisfied that the precautions which are taken to enable its voice to be heard—as I said before, it ought to be heard—in every part of the world, do not let the gentlemen whom I see around me—naval architects, engineers, and others, of great experience—lay all the blame where it should not be laid, namely, on the Naval Constructor or the Constructor's Department, or those naval officers who have charge of the construction, and who have done their best always to get a proper, efficient, and powerful Navy together, but let the blame lie where it should; and I have no hesitation in saying, as the result of ten years' experience, that the blame rests mainly with the House of Commons. That may be an audacious thing to say, but it is the want of sufficient money being allowed by the House of Commons that has almost constantly kept our ships back, and which has influenced—although it ought not to have influenced—our statesmen from telling the truth boldly and letting the country be aware that its Navy is disorganised, unclassified, groping its way in the dark, and is not allowed to be made what it ought to be made, and which, if it were made what it ought to be, would resemble in many respects the Navy which Mr. Scott Russell has so admirably sketched out to us to-day. As our time is so far gone I will not trouble the Meeting with any further observations, thanking them for the attention with which they have listened to me.

Admiral the Right Hon. THE EARL OF LAUDERDALE, K.C.B.: The subject of Mr. Scott Russell's Paper is, no doubt, one of great importance. Unfortunately I cannot hear very well, but if I understood the Paper rightly, the question before us is, what description of vessel it is desirable for Great Britain to have in the future. Mr. Scott Russell has shown us what we have had in various years, but the expense he has not laid much stress upon, nor the impediments which are thrown in the way by the House of Commons. The House of Commons will always throw impediments in the way until such a Meeting as this, composed of naval architects, engineers, naval officers, and others connected with the Navy, show them that the thing is absolutely necessary, and that they have designed the class of vessels which ought to be built. If that can be shown to the House of Commons, I am perfectly satisfied that the House of Commons will give the money necessary to build such ships; but it is such a great and important question that the House of Commons naturally hesitates about it, particularly when there are dissensions among yourselves as to the style of vessel required. Now, with regard to the description of vessels given in the list before us, I daresay we differ. I see there is one list which begins with the *Warrior*. For my own part, I look upon that class of ships as altogether obsolete—I mean with reference to their armour and their guns. I agree with Mr. Scott Russell that we ought to have such ships as the *Warrior*, but they must be so far protected with armour as will meet the present guns. I leave it to the constructors to do that. I think Mr. Scott Russell said that they must have a great number of guns. I do not agree with him there. I think if you have these enormous guns you cannot have many of them; and as to protecting them with thick armour, if you have many guns in the ship, that is utterly impossible; therefore we should only have a few guns.

Mr. J. SCOTT RUSSELL: You are quite right.

The EARL OF LAUDERDALE: Then we come down to the modern ships—the turret-ships, such as the *Devastation*, and that class. Now, for myself, I do not look upon those as ships at all. They are really nothing more than the most powerful floating batteries. Shipbuilders may call them ships, but no sailor ever would, and I cannot bring myself to call a vessel like the *Devastation* a sea-going ship. She is

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no doubt a most powerful destructive floating battery. As regards the *Inflexible*, and ships of that type, I can give no opinion on the matter, because I believe they are not built. Then the next question is what kind of vessels do we require the largest number of—I mean vessels to protect our trade? There are employed in the trade of the British Empire somewhere about 35,000 ships; I believe in those ships we have 350,000 men; and we have to protect all that property besides our Colonies. In case of a great naval war, unless we could cover the sea with vessels, our trade would be in jeopardy, and we might lose our Colonies. As to having steamers—regular gunboats as Mr. Scott Russell advocates—any vessel that is entirely dependent upon steam never can cruise about for a long time, because she must be a small vessel, and therefore would not be able to keep the sea. Therefore it seems to me we must have vessels something of the *Alabama* class—swift-sailing vessels which can keep the sea, never using coal except when actually chasing an enemy. With regard to ships for coast and harbour defence, I agree with Mr. Scott Russell, that the *Devastation* class would be most valuable, because you can build them to any size, and they draw very little water. Now I will say one word about a remark of Mr. Scott Russell's with regard to guns. I will not say that I agree with him with regard to guns. I think he said that we had made a mistake by having small-bore guns instead of large-bore guns. Now I differ from him entirely. He says the small-bore gun does not carry the weight of shell or shot, but that the small-bore gun—the rifle gun—carries it in length. With the large guns I suppose Mr. Scott Russell intends to use circular shells?

Mr. J. Scott Russell: No; in all cases long—equally long in both.

The Earl of Lauderdale: Then, if you make the gun long enough and strong enough, no doubt the big gun will be better; but you must be tied to size. At any rate, on board ship that has been the great difficulty in all the trials which have at present taken place. The 12-inch or moderate-size bore penetrates rather better than the very big one, because the large round shell shakes but does not penetrate. Those are the only remarks which I desire to make in connection with this subject.

Mr. J. I. Thornycroft: I would beg to make a few remarks in defence of the ships which are now built by the Admiralty, because I believe the immense size and penetrating power of modern guns is such that it is quite impossible to armour ships entirely; and it has been recommended by several gentlemen that ships of the *Warrior* class should be armoured, as I understand, throughout. Now, the penetrating power of modern guns has shown that that is impossible, and the ships of the *Thunderer* class are only armoured to a very limited extent, and part of the upper works are almost undefended. To my own mind that would appear to be really the true principle; and I do not think there need be any hesitation in the country in accepting this as the sort of vessel which is suitable. But I would venture to recommend that the unarmoured portion might be extended to a greater height above the water, so as to make these ships really capable of carrying sail, and the raised structure would enable the ship to be a sailing ship until she got into action; and then, when the ship was penetrated (and that is a contingency that would only happen in war), she might be designed as to be so stable that after destroying her enemy she could get safely out of action.

Captain J. H. Selwyn, R.N.: Perhaps I may be allowed to make a few remarks on Mr. Scott Russell's Paper, which I must say has interested me very much indeed. It seems to me that the question which Mr. Scott Russell has left out of consideration, in the beautiful picture which he has drawn of our future Navy, is the question of the duration of speed. I should have liked to have seen on those Tables

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some account of how long the speed claimed—13 knots in some ships, and 14 knots in others—could be kept up; because it is perfectly absurd to ask seamen to trust themselves—as in the *Nymph* (which is a vessel of the most recent construction) they have been asked to do—to a vessel which is not fully competent for sailing purposes, and is still less competent for steaming purposes. She runs two days under full steam. How that may be prolonged by the use of expansion adaptations I cannot say, without special reference to the ship; but what I would beg you to observe is, that the instant the ship begins to go slowly, she loses her whole efficiency, because if she is passed at all by a ship of the enemy, that enemy has not only the choice of bringing her to action, but of going away and doing damage before he can be overtaken; which, in the West Indies or in the Colonies, would be irreparable. Therefore the duration of the speed of a ship is a quality which should be closely looked after. The third class of ship which Mr. Scott Russell has spoken of as being desirable for the future Navy, is one to which all sailors will turn with a great deal of pleasure, because he would provide us there with a habitable ship, a seaworthy ship, a sailing ship, and a ship that would carry guns in sufficient quantity; and denying us only one thing, for which sailors have never been so much anxious, namely, very large protection. We do not want, and never did want, to be better protected with armour. We never wanted more protection than would be afforded us by proper gun carriages, and by the water itself outside the ship. That, I venture to suggest, is the true solution of the whole difficulty. Perhaps I may be allowed to say—as Mr. Scott Russell has referred to it, and it is a perfectly legitimate subject of discussion—that the instant anybody gives us Major Moncrieff's gun carriage, or a gun carriage which is capable of going below water with efficiency, then we have armour which no future shot can pierce; and it becomes possible to return to fully masted and fully steam-powered ships, to go all over the world, carrying their crews with them during peace, and perfectly prepared at all times for war, without the necessity of this awful reduplication of armour, which tends, every ten years, to make our ships obsolete. With regard to the gunboats of which Mr. Scott Russell spoke, I quite join with him in saying that they ought to exist in swarms. That is the true way of having protection for our shores, for no heavy floating battery can ever offer half so much protection, at the right point and at the right time, as a swarm of gunboats would. There is no difficulty in making those gunboats. They will not be, as was assumed by one of the speakers, necessarily very expensive. There is a representative value in those Tables, roughly speaking, of ten millions sterling; and if one million out of the whole had been devoted to the elaboration of gunboats of the calibre which Mr. Scott Russell has shown can be built, with high speed, and to carry the heaviest gun now known, we should have a fleet on which we could depend,—and which would, at least, give us a powerful defence, I do not say for our shores, but for our coaling ports, upon which the efficiency of our Navy must depend. I must take exception to the statement that turrets are well calculated for narrow water attack. If the narrow water is accompanied by low shores, then turrets are a good defence; but the instant that those turrets find themselves approaching a bluff on which is a battery with guns of high command, the turrets no more dare go near it than go ashore, because the vessel would be certain to be pierced clean through the bottom. The shot would go in at her deck and out at her bottom. As regards Mr. Scott Russell's second Paper, which was devoted to the floating gun carriage, I thoroughly agree with him; but I would beg him to answer me one question, namely, whether it would not be wiser, where we have to deal with a steady platform for gun carriages, to have a light-draught steady platform; and, while taking the circle as the best form possible, to take only a small segment of that circle, and to extend its width and length—to take for instance very nearly the form of the spoon bow, extending it as much as

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would give precisely the same floating power as the vessel which he has drawn, but having the enormous advantage of a light-draught vessel. She would be a steady platform; she would move with the waves; but she would not draw such an amount of water as would prevent her from going over shoals and shallows, where alone sometimes she could hope to escape from more formidable foes. As I have already said, the expenditure of ten millions of money, as represented in the Tables on the walls, has been largely devoted unfortunately to experimental purposes, and to some experiments which were not believed in even by those who made them; and I must say that, had the counsels of this Institution been listened to long ago, a great many of those experiments would never have been made at all. The future expenditure need not certainly be larger than it is at the present time; but if it proceeds upon well-considered grounds, and after proper discussion, I think by far the larger portion of it will not be liable to the reproach after ten years of having been devoted to producing obsolete ships.

Mr. N. Barnaby: Mr. Scott Russell has, I think, explained the reason why Captain Selwyn is able to complain of the great number of experimental ships,—namely, that nearly all our ships are experimental ships. They will not build two of them alike as a rule. When a ship is acknowledged to be good, and there are a number of ships indicated in the Tables on the walls which are acknowledged on all hands to be thoroughly good ships, why it is preferred to have a new type, I cannot always understand; but that is certainly one reason why there are so many ships which may be called experiments. With regard to Mr. Scott Russell's three types of ships, I think you will have seen that the first type and the third type are represented in the British Navy. The second type, the long, fast, low, sea-going gunboat with one heavy gun, is not represented in the Navy. That would be a ship which our sailors would not use at present. That it is right to build vessels for fighting purposes which cannot properly be called ships, I fully agree with Mr. Scott Russell; but when Mr. Scott Russell remembers what has been said, and what is being said, about the first attempt which has been made to send to sea a powerful fighting machine without masts like the *Devastation*, he will see at once how difficult it is to pass from a ship to a fighting machine in the English Navy. I do not think I need say any more on that matter, but I should like to say a word or two with regard to the question of guns. The rule among gunners—I do not know why they make it a rule, and perhaps they are wrong in making it—is that the length of a gun should bear a proportion to the calibre of the gun. Now as we have already got to a gun of 30 feet in length, if the calibre is to be very much increased and the rule is adhered to, we shall find the gun of a most uncomfortable length, and shall be hardly able to do anything with it.

Admiral Stewart, C.B.: Perhaps I have to a certain degree misunderstood Mr. Scott Russell's diagram of the ship. As I understand, the ship which he has sketched to us is intended to encounter waves and seas, and has a certain height of freeboard; but if I understand that diagram right, she is not intended to be armoured above the water-line.

Mr. J. Scott Russell: I did not go into the question of armour at all.

Admiral Stewart: I understood that the armour extended to the water-line.

Mr. J. Scott Russell: That has no relation to that kind of ship. That is only the form of ship which gives a stable platform.

Admiral Stewart: I understand the principle on which the ship is to be armed is that commonly

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known as Major Moncrieff's. The gun rises to fire and falls to load. I suppose such a ship would require to be protected with armour round the sides; otherwise, if the part of the ship which is above the water-line was pierced, in what manner would you prevent the sea from coming in and going down into the centre well, if I may so call it, where the gun descends to load. This has always appeared to my mind to be a difficulty with this plan of arming of a ship. Such a ship, to encounter seas, and to have good habitable accommodation, must have a considerable height of freeboard; as the gun must rise above all that to fire, a large space must exist in the middle of the ship, from which it would be necessary to provide means for keeping out the seas which the ship might encounter.

Mr. C. W. Merrifield, F.R.S.: I will only detain you a couple of minutes with a few observations. I think there is one thing above all others, in the first instance, that we learn from the discussion which we have had before us to-day, and that is, that the country especially—I will not say the Government—should trust its own naval architects a little more than it does. It is evident that, from one cause or another, the professional naval architects of this country, who have designed the ships of the Navy, have not had fair play. I do not propose to discuss any points, if any such there be, that may be at issue between either Mr. Reed, Mr. Barnaby, or any past or future Constructors of the Navy, but I am quite convinced that the country would gain a great deal if it allowed the man—with whom the construction and the plan of the ships must, after all, finally rest—to exercise his own discretion a little more. The naval architect is not professionally a fighting officer, and it is doing him a great injustice, when we oblige him to fight hard for his plans, and to spend half his time, not in designing and considering what is the best thing to do, but in fighting his plans through, with the Admiralty in the first place, the House of Commons in the second, and the country in the third. The second point which I have to notice is, that we have not only to complain of the House of Commons in the matter of economy and ill-judged expenditure, but beyond the House of Commons lies the country, and I do not think that the country, of which the House of Commons is to a great extent the mere exponent, at all understands the question at issue. We have been singing "Rule Britannia" until we have actually brought ourselves to believe that Britannia must rule, without taking the ordinary means of attaining that object. It is true that it is commonly said we are unprepared for war now. But so we have ever been; and we have always gone into all our wars unprepared, and sometimes we have come out of them well. We have latterly always done so, but we have done so because we have had the protection of the narrow seas; but if we go a little farther back—to the time of William the Conqueror, and even later, in the time of King John—we cannot but remember that the narrow seas have not always been a protection. Steam has done very much to take away that advantage from us, and I think if we are not a little careful about singing "Rule Britannia," we may find that we have trusted to it a little too much; and although it is commonly said, that an enemy may invade this country but that it would be impossible for him to hold it, in my opinion the holding of this country would be a great deal more easy than the invasion of it. I strongly commend these observations, and seriously commend them, although I do not expect them to carry conviction, to the consideration of my fellow-countrymen.

Major Moncrieff, F.R.S.: I should wish to answer a question which was put. It was asked in what manner the water could be kept out of vessels armed on my principle, alluding to the large opening required for horizontal ports. I think Mr. Barnaby will agree with me that any one who has seen the designs will admit that this is effected with the greatest facility by one of two methods, *viz.*, either by an

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iron hood or cover above the deck, or by self-acting shutters which close over the port. In either case the water is effectually excluded from the vessel.

Mr. CHARLES LAMPORT: I shall not occupy the attention of the Meeting more than a few minutes, but I wish to put before it this particular view of what I conceive to be our best defensive policy—namely, that we should rather cultivate the power to produce the best type of ship when we go to war, than that we should be discussing and trying to make out what would be the best type of ship for the present, which we know from the experience of the past is very likely to be found obsolete when we may be called upon to use it. Now at the present moment I believe we have about forty-seven or fifty ships of war. I believe they are looked upon, throughout the country generally, as being equal to all the navies of all other countries in the world besides. Gentlemen, numerically, no doubt, they are so; but when you bear in mind that the great portion of our present fleet is not capable of resisting one of Whitworth's 70-pounder guns, to say nothing of 700-pounder guns, I think that you will join with me in coming to the conclusion that such a fleet is not one which we can fairly rest upon for the defence of this country, and for the protection of her commerce in time of war. The answer to this observation may be, Well, are we to do nothing? No; certainly we are to do everything we can do on purely defensive principles; we ought to keep the enemy at bay, but we ought already to have the producing shipbuilding power fostered and developed throughout the country, so that if and when war comes upon us, the whole manufacturing energy, the whole skill and capability of this country may be directed to the production of that type of vessel which is really efficient. The commentary on the whole of our fleet, the whole condemnation of it from first to last, is that ship which Mr. Barnaby's department, if not he himself, has designed—the *Inflexible*. I believe that ship is constructed to have armour plates equal to meeting the guns of the present time—armour plates of 2 feet in thickness. What in comparison will 4½-inch plates do for the defence of our ships? Out of the whole fifty, twenty-seven of them have only 4½-inch plates. Now, Gentlemen, what are we to do? That is the great question. It seems to me we have two things to attend to in case we go to war. In the first place we must protect our shores, and in the next place we must defend our commerce. How shall we defend this country? We have torpedoes, which form a most admirable defence; and we have also the power of cheaply floating large guns, and of circulating them round our shores, in order to keep off an invading enemy. We have ships which I may typify by the name of the *Staunch;* ships that float only as a gun carriage, and ships which have this great advantage—for I consider it is an enormous advantage—that if they had to retire within a harbour, if only we had prepared for them small well placed basins into which they could go, then they would form the best gun carriages that could possibly be, and in the best positions, to answer efficiently as land fortifications. So much for the question of our defences. As regards our commerce, it is perfectly clear that unless we have ships which can outsail the cruisers of other nations, we cannot protect that commerce. We are particularly vulnerable as regards our commerce. The ships of this country, as we know, cover every sea, and are to be found in every port of every country in the world, and if they are to be devoid of protection, woe be to the prosperity of England. How are we to protect them? Not by our *Warriors*, not by our *Devastations*—not by ships of that class at all; but by a numerous fleet of ships of a class which can outsail the cruisers of most other countries. If we can do that, and if those ships can carry guns and can select their time to attack, and if they can, in case of necessity, cover every sea, and frequent every port to protect our commerce, then we shall have the best—I will almost say the only—

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means of protecting the commerce of this country. I do not know whether gentlemen are aware what the extent of our commerce is. There are eight millions of shipping belonging to this country at the present time: those ships are manned by something like 350,000 sailors, and they perform voyages which, in the aggregate, as regards tonnage, would amount to something like fifty or sixty millions of tons annually sent from this country and brought home to this country. The value of our shipping is nearly £100,000,000. Now, Gentlemen, we should peril the whole of this and the trade depending upon it if we were to go to war with a little country like Brazil, or China, or any other country of that kind; and depend upon it, we peril the safety of a large class of our population. Therefore, if we do not protect this commerce, we strike a blow, or permit a blow to be struck, at the very heart and vitality of the prosperity of England. Let us, therefore, have defence; let us give over building these *Devastations* and great ships, which look well and sail well upon paper, but which, in case of war, when they would be require for our defence, would be too few to keep the numerous vessels bringing over numbers of men at bay; and would be utterly useless to protect our diffused commerce which permeates and covers the seas.

Captain SCOTT, R.N.: I should not like the gentleman who has just addressed us to go away with the idea that all those ships which he has referred to are so useless and so obsolete as he and some of the able gentlemen who have spoken before me seem to consider, because those ships are, I think, still capable of doing admirable service. All of them are capable of carrying heavy guns on the upper decks; and such vessels as the *Warrior* could easily have a 35-ton gun on the upper deck. The *Minotaur*, the *Achilles*, the *Northumberland*, and the *Agincourt*, could have two or three 35-ton guns; and therefore, as we cannot get the large sum of money, which Mr. Scott Russell names, from the country—and it is clearly shown that we cannot—it is far better at once to make the most of what we really have. I believe we can do this without much difficulty, and at the very small expense of say £100,000 have such a re-arrangement of guns as would fully double the force of all those vessels which have been pronounced to be obsolete. There is another point that I wish particularly to bring before you. A great deal has been said about the penetration of armour, and a great deal of nonsense is still talked about guns beating the armour, and *vice versâ*. It is the greatest possible rubbish, for you have only to increase the power and number of guns to destroy any thickness of armour. The armour cannot return the fire, and whatever the defensive armour of the ship may be, she must carry guns which will return and subdue the enemy's fire. Our principle in England must be that of quick and sharp *offence*, such as has always proved the best *defence* in our naval wars. I am not at all sure that in mounting very large guns, of 80 tons or more, we are not getting into very serious difficulties. The large guns can be easily hit; and whatever England may do towards increasing the accuracy of firing at sea, other nations are greatly improving their practice, and hence I believe that such a large gun as one of 80 tons will be easily hit: I have not the slightest doubt that a 64-pounder shot fired at a high velocity, would so damage that big gun as to make it utterly useless. This is a matter for serious consideration. I think it is also a matter to be carefully considered whether the guns are not really the most important things to be protected, or at all events, next in importance to the engines. Captain Selwyn has brought before you the facts as to the paucity of gunboats on the shores of England. No doubt we do greatly need numerous gunboats of a much more powerful character than any we now have, both for attack and defence. We ought to have gunboats which can mount ordnance as powerful as any that can be brought against them. What is the use of a gunboat with an 18-ton gun,

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when a 35-ton or a heavier gun is brought against it protected by armour that cannot be penetrated by the 18-ton gun? With regard to cruisers, nobody can doubt that we want a very large number, and that without them our commerce must be swept off the seas at the commencement of a war. A sufficient number of cruisers we have not got. France is fast building cruisers. As Sir Spencer Robinson has explained, the class of vessels to be built does not rest with the constructive department at all. Instructions have only to be given, and the department would go on building such ships as the *Raleigh* and the *Inconstant*, which are magnificent cruisers. I cannot agree at all with the idea that fast vessels can be small, because if you are to have speed you must have size, and unless you have size you cannot have any carrying capacity, and a vessel which has no adequate carrying capacity cannot be either an armoured cruiser or capable of efficiently carrying into action men and guns. The question for our consideration is—how much armour are we inclined to give up in order to have more powerful guns? That is the principal question. It is the question which has been debated in the papers, and no doubt you have seen the correspondence between "Seaman-gunner" and Mr. Reed. With respect to this correspondence, I may say that "Seaman-gunner" has gone on the assumption of the advantages being on the side of numerous light guns, as against fewer and more powerful guns. Our unarmoured vessels are few and far between at the present time, and if they can be chased off the seas by lightly-armoured hostile cruisers, whether Chinamen or Brazilian—I only name these as an illustration, and not desiring to say a word against either of those nations—what protection will they be to our commerce? The *Raleigh* is mainly armed with light guns of very little power. Such guns will have no effect whatever against an ironclad; but a new *Raleigh*, with the same tonnage, could carry four 18-ton guns, and might in addition be perfectly well armed against the attacks of torpedo and other vessels. But, on the one hand, and that is a great difficulty in the way of constructors, they have to contend with those who go in entirely for a few very heavy guns, and on the other hand to contend with those who go in for a large number of light guns only. I think both are mistaken. You really want light guns and also heavy guns; the large gun alone will not be able to maintain its fire against a number of well-directed small guns discharged at it. In the contest, however, which has been carried on in the public papers as to heavy or light guns, it seems to me to have been entirely left out of consideration that the shell of the heavy gun is far stronger than the shell of the light gun. I think it is probable that in striking at an acute angle every one of the light shells would break up. I believe 1-inch thickness of side armour would break them up of a certainty; and I am not at all sure that on a light shell striking the side of an unarmoured vessel the same effect would not be produced. On the other hand, a heavy shell will generally penetrate, and if it penetrates will produce a far greater effect. There is another point, which is this: that the heavy gun has greater accuracy, a flatter trajectory, and more power, and therefore it is much better for the main armament. Another consideration with regard to having a number of light guns is that the smoke from one gun interferes with the pointing of the others. I think you would find that a great mistake had been committed were one of our unarmoured vessels to meet (as it would be sure to do on the declaration of war,) with small ironclads, and be obliged to retreat, for she could do nothing with light guns. I think Mr. Scott Russell is quite right in pointing out that the ship is a gun carriage. I agree also with what he has said as to large-bore guns. We commenced with a large (13¼-inch) bore gun firing 600-pound projectiles. The gun itself was not so well built as guns are now, and the consequence was it failed. Then we gradually went back again, decreasing the charge of powder and making the calibre smaller. Now we are going the other way and enlarging the calibre. I think the question of the guns as well

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as the question as to the ships which should be built requires most careful consideration, as we have only a limited amount of money to expend. I trust I may be excused for saying that if the so-called *brutal* powder necessitated a very thick breech, and the gun was built in accordance with the requirements of that very powerful powder, it should have quite different proportions for the weak powder at present in use. If we had the larger calibre guns, which Mr. Scott Russell has indicated, we should obtain a very high velocity; the shot would stick to their work far better, and we should have, under all circumstances, a much better result, and not require guns of 30 feet and upwards in length.

The CHAIRMAN: It is quite unnecessary, and would be presumption on my part, to add anything to the very interesting discussion that has taken place, but I think I am expressing the feeling of the Meeting that the Papers which have been so admirably brought forward by Mr. Scott Russell, and the discussion to which they have given rise, are most well timed. I am especially alluding to the remarks which have fallen from Sir Spencer Robinson, which I look upon as having a most important value on account of the great experience which he has had, and the important part we know he has taken in the reconstruction of the Navy.

Mr. JOHN SCOTT RUSSELL, F.R.S.: I will in the fewest possible words answer the questions which have been put to me in the course of this discussion. The first question had relation to what my brother engineer would not allow me to call by its true name of an oval. I am quite sure that our Chairman is perfectly competent to distinguish between an oval and a circle, and I will ask him if he thinks the figure I drew is an oval or a circle. Allow me to say that I did not mean a circle, because we have all had plenty of experience of the circular barrel which my friend who has left (Mr. Bramwell) quoted. He told us to take the cigar ship. We all know the story of the barrel, and that a cask floats very well, but I do not know that a barrel or a cigar is a perfect type of the highest class of naval architecture. I think the naval architects here would find that so simple and cheap a form, that they would be very much disposed to adopt it unless they had serious reasons for thinking that the barrel and the cigar were not the best possible ships. I merely wish to correct the cutting of the bottom of the figure which my very ingenious critic wanted to do. I am happy to confirm his statement that the proposition is not new—that it is old; that a friend of mine, a very clever man, called Assheton Smith, whom we all remember, and who had something to do along with me in devising the wave system, invented this perfect mode of improving the bottom of an elliptical or circular ship. He, being a wealthy man, built a ship according to that invention, and I am afraid he and I quarrelled for life, because I told him that the improvement he had made in this beautiful ship of his would be a failure; and if he had turned out right, and I had been wrong, I do not think he would have been angry at all; but as he turned out wrong instead of right, he threw all the blame upon me. That has been proved a failure, and I say that merely that our friend may be saved from investing his own money, and his friends' money, in making an experiment which we have tried already, and got all the results of. Now, with regard to the circular form, I hope you all understood that I did not mean making a ship in the shape of a barrel. I take it as the general type of ship with round bilges and a rising floor, and somewhat rounded sides instead of straight sides; and therefore having the qualities which I think all seamen recognise as essential qualities in a good ship. If I wanted to make you think that a pretty ship, I could only do what I left you to do, namely, put on a nice keel here, and round it down beautifully, as you remember our ships were in old times, and it would be the type of some of the best old ships which we can remember in the British Navy. I am not saying that that is anything new. I am not advising

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a circle or a particular ellipse, or anything of the kind; but what I am saying to you is this—build a ship with good round bilges, which we know are essential for a good sea ship; with tolerably round sides, which we know are good sea qualities; and place these particular points where I have told you, and concentrate and keep as near to this point as you can the centre of all the weights. I say, and I undertake to satisfy anybody who is a naval architect, that you will get in that way the steadiest possible ship—not in a calm, nor in a smooth water, for they are all steady enough there, and we need have nothing to do with that, but I am talking of a good sea boat. The next point I have to notice is this. I am very grateful to you all, and, as an Englishman merely, extremely grateful to Admiral Sir Spencer Robinson, and to Mr. Barnaby, for having had the courage to speak out. I did not venture to speak out a tenth part of what I feel and think on this important subject, nor do I intend to, but I do say as an Englishman and a patriot, that I am profoundly grateful to every one of you who have treated this question at this moment as a question of serious national interest. I assure you that I think this so earnest a matter, that if I were—as some gentlemen here are—in our Houses of Legislature, there is nothing I would not stake as an Englishman, upon taking the responsibility at once upon myself, or if I were part of a Ministry, upon the Ministry, of having a liberal sum of money voted by the House of Commons to an existing Government, they taking upon themselves the responsibility of saying to the country, "We have a fleet in perfect order, do not be afraid of going to war to-morrow;" because I have watched all the wars that have occurred in my lifetime very closely, and I know that when we say we are all in order, and feel we are all in order, and everybody feels we are ready for war, other people feel it too, and they take good care not to make war; but when you say you are ready and you are not ready, then you will tumble as you have done before, and as other nations have done not long ago, into the abyss of misfortune, and that is in consequence of saying, "Oh, we are such clever people we shall always be ready, "and it is of no use our making any preparation." Now, with regard to guns let me say one word. Understand distinctly that I have not said a word about the weight of the gun. All I have said is this. I take a gun of the given weight which you think handy for the purpose, and instead of giving you a small bore, I give the gun a larger bore for naval purposes than you give for land purposes. I do so because I know that I can in that way get, with less strain on the gun, a greater initial velocity, and I know also I can get it with a shorter gun; and allow me to say there are great errors in gunnery. One error is in supposing that there is any fixed proportion between the bore and the diameter of the gun, and in supposing that there is any fixed proportion between the bore and the length of the gun. The things have nothing to do with one another, and it is the fact of these traditions in the Navy, and out of the Navy, which makes us continue to copy guns as we once continued to copy ships. Did we not once all say that three times the beam was the only length you could give a ship? Did we not then make it four, and do not we now make it five, six, and seven times; and is not the only debate now whether we shall make it eight or ten times? A gun and its length have nothing to do with each other. The things which have to do with each other are these—the purpose you want the gun to serve, the size or weight of shot or shell you want it to carry, and the initial velocity with which you want it to strike the enemy. When you take these as the conditions of the gun, make the gun to suit those conditions, and if you then say you want such a gun, with such a velocity, for such a quantity of shell, and for such a penetration of armour, and you can give 18 tons for its weight, then call in all your best artillerists and say, With these conditions how can you make that gun of the greatest effect? That is the problem we have to solve and throw all your traditions to the winds. Allow me to say that I was extremely delighted to see that the

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inventor of the gun-carriage (whom I have not seen now for ten or twelve years) present in this room when I alluded to the Moncrieff gun-carriage, and that he has given you the information that that carriage would rise comfortably above the water-line, and fire well above the water-line, and be snug below the water-line at another time. Whether he, or my honourable friend, or myself, could invent the cleverest way of closing up the gun, and opening it, and making a vessel seaworthy, so that the water might always go free, is a question of mutual dexterity, but I think all three of us could manage it.

Admiral Sir SPENCER ROBINSON: Do I understand you rightly that those experiments which Whitworth made so conclusively, as I thought, and I daresay as other people thought, as to the relative proportions to be observed between the calibre of the gun and its length, are entirely erroneous?

Mr. J. SCOTT RUSSELL: Entirely erroneous.

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ON IRON AND STEEL FOR SHIPBUILDING.*

By N. Barnaby, Esq., Chief Naval Architect of the Royal Navy, Vice-President.

[Read at the Sixteenth Session of the Institution of Naval Architects, 19th March, 1875; Joseph Woolley, Esq., LL.D., F.R.A.S., Vice-President, in the Chair.]

Engineers and shipbuilders are, I think, generally of opinion that steel must eventually displace iron in shipbuilding, both for hull and machinery. I do not fully understand why the rate of progress towards this desirable end is so slow. Looking back ten years, I am disposed to say that (excluding armour plates) there has been no sensible progress in the shipbuilding material in actual use, whether of iron or steel, with the single exception of the introduction and partial development of the Whitworth process of compressing fluid steel. So far as our experience of it goes, the material produced at the Whitworth Works is as nearly perfect as can be imagined; but it is not yet fairly in the market, and the prices promise to be almost prohibitive to shipbuilders.

No doubt excellent steel is produced in small quantities by the converter and the bath at a much cheaper rate than it could be produced ten years ago; and, where the management is strict and careful, considerable quantities may be delivered of trustworthy material. Nevertheless our distrust of it is so great that the material may be said to be altogether unused by private shipbuilders, except for boats and very small vessels, and masts and yards; and marine engineers appear to be equally afraid of it.

In October last, I had an opportunity of seeing the iron and steel materials used in building the ships of war for the French Navy. I am bound to say that not only was it, so far as I could see, of excellent quality, but there was an extended use of steel, which argued greater confidence in the material than we have ourselves. In the large new masted iron-clad *Redoutable*, building at L'Orient, steel is being employed for the frames, the beams, the deck-plating, the bulkheads, the plating behind armour, and the inner bottom. There was thus only the outer bottom, and the rivets throughout the ship,

* Received 6th March, 1875.

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from which it had been excluded. Two other large iron-clad vessels of war, the *Tempête* and *Tonnerre*, designed by the same officer as the *Redoutable*, were building at Brest and L'Orient, with the same distribution of material. About 600 tons of steel plates, made by the Bessemer and by the Martin-Siemens process, had been already used in these vessels, and of steel angles and double-tee steels 30,000 or 40,000 running feet had been worked into place. This steel had been produced mainly at Creusot and Terre-Noire.

Prior to the commencement of these vessels in 1873, the use of steel in French ships had been limited to masts, boats, and very small vessels. Neither iron nor steel has hitherto been used in the French National Navy to any considerable extent. The only sea-going fighting ships they have complete, built of other material than wood, are three in number, *viz.*, the *Friedland*, *Héroïne*, and *Couronne*.

I may state in passing, that in France and all over the Continent of Europe the system of construction now adopted for iron ships of war is almost identical with our own. The French translation of Mr. Reed's *Shipbuilding in Iron and Steel* is the text book. The steel employed in France is made under Government inspection at the various manufactories, and is not tested in the dockyards upon receipt. The quality is defined by the conditions that it shall have a tensile strength of 30½ to 31½ tons each way, and shall have 22 per cent. of ductility. It is in fact as nearly as possible the same description of material as is supplied to the Admiralty by the Bolton Steel and Iron Company, *i.e.*, well-made and carefully selected Bessemer steel. M. de Bussy, the designer and builder of these ships at L'Orient and Brest, was good enough to have some tests of the material made in my presence and in accordance with my wishes.

The points of greatest interest to me were those connected with the mode of working the material. The use of iron hammers in bending it to form was scrupulously avoided, and the angle bars and double-tee frames were curved and bevelled by pressure, various devices for doing this having been initiated at L'Orient. The double-tee frames and beams were of the section shown, and they were made in one length for the beams of the ship. I am indebted for the annexed sketches to a little book entitled *Etude sur l'Emploi de l'Acier dans les Constructions*, written by M. Barba, "Ingénieur des "Constructions Navales," at L'Orient, and published this year by Baudry, Paris. It is a most interesting little book, inasmuch as it records the results of all the recent experiments made by M. de Bussy and his able coadjutors, M. Barba and M. Godron, and describes the various mechanical devices which they have adopted for coaxing and humouring this material. Speaking of the necessity for care in the manipulation of steel, M. Barba says:—

"If it is impossible to work the plates without hammering, or without local

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"pressures of great severity, or if the curvature given is considerable, it is necessary to "proceed with care and skill to avoid ruptures in the course of the operation. The "hammering ought to be done with light blows delivered over as large a surface as "possible, and the curvature ought to be produced not at once but by successive stages. "After the work has been done the plate should be promptly annealed." He says further, "One ought to avoid as much as possible partial or rather local heating. When "by careful treatment the plate had been brought to its proper form, the annealing "process should be immediately resorted to, and the heat should be applied very "gradually, for a sudden augmentation of temperature in a point where the molecular "tensions are already exaggerated might cause a rupture. When the plate has been "regularly heated to a sufficient temperature, and is left to cool slowly, the bad effects "of the local disturbances will be destroyed and homogeneity will be re-established."

The heating furnace used is a Siemens' gas furnace, and the plates are generally allowed to cool upon the floor of the shop, taking care that it is dry, and that no part of the hot plate is allowed to come in contact with any rapidly-conducting material. I could not read the sentences I have quoted above without the reflection that a material which needed such care in its treatment would stand but a very poor chance in an ordinary ship-yard. I for one should feel very doubtful about a ship built of it for myself, unless I could see every plate worked.

The ordinary steel angles in use at L'Orient cost, I was informed, about £27 per ton, and the double-tee bars about £41 per ton. Add to this the cost of such careful labour as I have described, and it will be found that ships so built would be costly.

It must not be supposed that the question of cost does not press hardly upon the constructors of ships of war. It is as much a ruling consideration with them as with private builders. The House of Commons, guided by the responsible Minister, fixes, at the commencement of each year, the number of men who shall be employed in the Dockyards upon new works, and the amount of money which shall be expended upon shipbuilding for the Royal Navy in private yards. The cloth being given to the Controller of the Navy, he must have out of it as many coats as possible of the various shapes and patterns required. He has to provide for the line of battle, for the protection of commerce in war, for home defence, and also for the numerous services required of the English Navy, the world over, in a time of peace. There is a growing necessity for higher speed in most of these ships, and for a multiplicity of steam appliances, and I need not tell you how this machinery runs away with the money. So it happens that we do not feel at liberty to build of the best possible material when that material is very costly. We use the material which, all things considered, including price, is, in our judgment, the best for the purpose.

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I claim, nevertheless, for the Admiralty, that we have done much to keep up the quality of iron in England, when the perpetual tendency of keen commercial competition has been to degrade it. Many appeals have been made to us to lower the standard of strength for first-class iron, in order to get the prescribed forge tests more easily at a reasonable cost; but we still maintain that 18 tons per square inch across the grain is not too great for first-class iron. I should myself be better pleased if it were 19, I should be prepared to bring down the tensile strength with the grain from 22 tons to 20 tons if the additional ton across the grain could be obtained, and the bending angles were not reduced.

It has been said recently that the iron used by the Admiralty is not good enough, and that we ought to be prepared to give higher prices. I entirely dissent from this view. We pay for iron for boiler making twice as much as so-called boiler plate can be bought for in the market, and our ship plates cost us only £3 per ton less. How much of this cheap material is in common use I will not undertake to say.

Mr. Crampton has recently succeeded in producing experimentally an excellent homogeneous iron in his rotary puddling furnace. By favour of Colonel Campbell, and the War Office, we have been able to experiment upon plates, angles, and bars made from Woolwich cast iron scrap. The results are most satisfactory. The hot forge tests are superior to those of Best Best iron, and the cold forge tests are equal to those of Low Moor, Bowling and Farnley irons. The tensile strength of the unpunched material is low and somewhat irregular. It ran in various specimens as follows:—With the grain, per square inch of unbroken section, in tons, between $17\frac{1}{2}$ and 23 tons against 22 tons of Best Best iron. Across—between 17 and $20\frac{1}{4}$ tons, against 18 tons of Best Best iron. The ductility in these specimens averaged $15\frac{1}{2}$ per cent.

This material when punched suffered so much less than Best Best iron, that the strength of the material when riveted up was superior to that of Best Best iron, and equal to that of Bessemer steel when the latter was punched, the holes left untouched, and the material left unannealed subsequently to punching.

The results showed as follows: $\frac{5}{8}$-inch plate, $2\frac{1}{4}$ inches wide, with $\frac{7}{8}$-inch rivet:—

	Strength of Material between the holes, per square inch.		Elongation in 6 inches.	
Bessemer Steel ...	16·34	... ...	$\frac{3}{16}$	
	13·75	Mean, 14·5. ...	$\frac{1}{16}$	Mean, $\frac{2}{16}$.
	13·44	... ...	$\frac{1}{8}$	
Crampton Iron ...	16·977	... ...	$\frac{9}{16}$	
	15·858	Mean, 16·434.	$\frac{3}{4}$	Mean, $\frac{10}{16}$.
	16·467	... ...	$\frac{5}{8}$	

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Similarly a $\frac{3}{8}$-inch plate, 2 inches wide, with a $\frac{3}{4}$-inch rivet, gave—

	Strength of Material between the holes, per square inch.		Elongation in 6 inches.	
Bessemer Steel ...	16·63	... ...	$\frac{1}{16}$	
	18·8	Mean, 18·54. ...	$\frac{1}{16}$	Mean, $\frac{1}{16}$.
	20·2	... ...	$\frac{1}{16}$	
Crampton Iron ...	17·74	... ...	$\frac{1}{4}$	
	17·74	Mean, 17·45. ...	$\frac{3}{16}$	Mean, $\frac{4}{16}$.
	16·88	... ...	$\frac{5}{16}$	

In another set of experiments with Best Best iron, the plate being $\frac{3}{8}$ inch, in strips 2 inches wide, and with a $\frac{3}{4}$ rivet, the results were, on an average of eight samples of Best Best iron with and across the grain, 16·66 tons per square inch of iron broken and a stretch of $\frac{1}{6}$ of an inch in 6 inches. The same number of samples of Crampton iron gave 18·56 tons per square inch and a stretch of nearly $\frac{1}{4}$ of an inch in 6 inches.

It is not necessary for me to say to you that Bessemer steel should never be punched without being subsequently annealed, or otherwise without having the punched holes rimed out; but it is interesting to compare the behaviour of the two materials under precisely similar circumstances. One of them, commencing with a tensile strength of 33 tons to the square inch, gives on an average of six experiments only half this strength after it has been punched; while the other, commencing with a tensile strength of say 19 tons, gives after punching 16·94 tons according to one set of experiments, and 18·56 according to another; or a reduction of only about 10 per cent. in one case and an almost inappreciable amount in the other.

On the whole this material is well adapted, in my opinion, for shipbuilding and boiler making, if it can be made uniformly in large quantities, of such quality as we have seen. It possesses this especial charm, it is homogeneous—there is no lamination or blistering about it. It is as compact and close as steel. I endeavour to persuade Mr. Crampton that great as his success has been, he must consider his work as but little more than half done. He must give us steel by his process.

The uncertainties and treacheries of Bessemer steel in the form of ship and boiler plates are such that it requires all the care which it has bestowed upon it at L'Orient to avoid failure. The question we have to put to the steel makers is, What are our prospects of obtaining a material which we can use without such delicate manipulation and so much fear and trembling? We have gone on for years using iron plates which are a compound of impure irons of different and unknown qualities welded together imperfectly in the rolls. We want a perfectly coherent and definitely carburized bloom or ingot of which the rolls have only to alter the form in order to make plates with

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qualities as regular and precise as those of copper and gun metal, and we look to the manufacturers for it.

I am ready for my part to go further than the French architects have gone, and build the entire vessel, bottom plates and all, of steel; but I know that at present the undertaking will involve an immense amount of anxiety and care. We ought not to be behind any other country in this matter, and it shall not be my fault if we are.

DISCUSSION.

The following letter to the President from Mr. T. R. Crampton was then read by the Secretary:—

"Sir,—The experiments made at Mr. Barnaby's request at Chatham on plates made from large puddle "blooms (produced from inferior brands of cast iron), appear to show that they are at least equal, if not "superior, to the best brands of iron experimented on at the same time for comparison.

"It is well known that if one homogeneous mass of puddled iron could be practically dealt with, "the lamination to which plates are liable would be prevented. There can be no further doubt on this "head. Colonel Campbell deals at Woolwich with these large masses from 10 cwt. to 12 cwt. with ease; "and with special appliances I have little doubt that balls of a ton in weight can be manipulated.

"The system of puddling in a revolving furnace heated by powdered fuel offers peculiar facilities for "producing these large masses, in consequence of the perfect control which the manipulator has over the "process. Wrought iron can, by this system, be produced from inferior cast iron, which is purified to "such an extent as to enable it to be converted into first-class steel. This has been proved in every case "when steel has been made, either in pots or in the bath; many tons having been made by parties who "have sent their own common cast iron, which was puddled under their own supervision, and afterwards "converted into steel by themselves. The tests compare favourably with the best *pot* and *bath* steels.

"Mr. Barnaby is aware that I have taken some interest in the steel question, but from his Paper I "think he imagines that I shall content myself by following up the success which has been achieved with "iron alone, since he urges me to produce steel. I can assure him that it is not my intention to neglect "either material. The steel question is one which must in time be solved, although at present steel "plates cannot be worked up into structures without a supervision it is difficult to give, and which good "iron does not require.

"Mr. Barnaby shows certain variations in the tensile strength of my iron which was experimented "upon. The treatment in working the plates was varied, and although soft plates were made having less "tensile strength, the ductile qualities are very superior.

"There appears to be no difficulty in producing wrought-iron bars from the same pig varying in "strength from 17 to 26 tons to the inch, and stretching, when cold, without breaking, from 50 per cent. "for the weakest iron, to 25 per cent. for the stronger kinds.

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"In consequence of the control which can be maintained over the process by my system, iron of "various quality can be produced at will. But it must not be thought that such a result is to be obtained "without a certain amount of practice, as each quality of pig requires a little experience as to the best "mode of treatment, as in hand puddling. It cannot be doubted, but that some process of manufacturing "homogeneous plates must in time supersede the present method, by which plates are built up of pieces, "and depend alone on good welding for their soundness. I am convinced that in very few years all iron "plates will be formed from one homogeneous puddle bloom.

"With regard to tests, I think that those systematically imposed by the Government have tended "materially to improve the quality of iron, even more than is generally supposed. These tests do not "find favour with manufacturers as a rule, although double the price is paid by the Government for "material so tested as compared with that ordinarily used in the mercantile marine. I think that great "good might accrue if the insurers of vessels would stipulate for certain strength and ductility as well as "quantity of material to be used, and *class* the ships in accordance therewith. Quality I believe is always "ignored. It is a great question whether the employment of bad material has not been the cause of "many accidents to our shipping, which have been laid to the charge of something else.

"My long acquaintance with many of those acting in official capacities at the War Office and "Admiralty has shown me that to obtain first-rate material is their primary object, and it is through "the assistance given to me by Colonel Campbell, the Superintendent of the Royal Gun Factories, and "his assistants, in carrying out the experiments, that has enabled those good results to be produced "which in his Paper Mr. Barnaby has attributed to me.

"I am, Sir, your obedient servant,

"T. R. CRAMPTON.

"*N.B.*—A few specimens of homogeneous plates made in the manner above described have been sent "for examination."

Mr. BESSEMER: Mr. Chairman and Gentlemen,—I would venture to make a few remarks, because I feel a very deep interest indeed in the question which has been brought before you. From the fear which has been expressed by Mr. Barnaby on this occasion one might be led to believe we had no experience in the use of Bessemer steel. I need scarcely tell you that it is only a few years since that our production of that article was 10 tons in each week. I may now tell you that its growing increase, and its application to almost every purpose in the arts, has brought the demand for that production to over 10,000 tons weekly. Now, Gentlemen, when a material is used for almost every imaginable purpose of the arts in this country, and is consumed weekly to the extent of 10,000 tons, I do not think that can be a material which people ought to be very much afraid of. The London and North-Western Railway Company have applied this material on their line to almost every purpose. At first they commenced with the rails. They doubted the propriety of using it for tires, but a little experience convinced them that it was the right thing for tires. It was said it could not be used for axles, but in that respect also the excellent manufacture of the Low Moor Iron Works—for it is an excellent manufacture—had to give way to Bessemer steel; and vast numbers of those have been for years and years in use, not giving way as readily as iron, and wearing four or five times the length of time. The point which touches most on Mr. Barnaby's Paper is its use as a riveted material. Long after the railway company had begun to find out how exceedingly durable and strong it was, they ventured to apply it for boilers and locomotives. I need not tell you that in the

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construction of locomotive boilers there are a great many difficult bends, and it requires a great many hammerings; and whatever the French gentlemen may say as to constructing those French ships-of-war, I have never in my life seen a copper hammer applied to a piece of Bessemer steel. The boilers made at Crewe are punched by the ordinary machines in the usual way. I am told that they lose in strength in punching about one-third, and that on annealing the whole of that one-third is restored. Therefore, when you have to deal with materials requiring that specific treatment, I think it is most unfair that we should be asked to judge of it unless that treatment is followed out. I have before me a number of samples of Bessemer steel which have holes $\frac{5}{8}$ths of an inch in diameter punched in them, and drifted out with a big wedge driven by the heavy blows of an iron hammer until they assume these sizes. These samples are the standard that has been adopted on the London and North-Western line; and that is the test to which every one of the plates that go into their boilers is subjected. Two pieces are cut off, one is subjected to this dreadful punching process, and the other is bent in the way in which you see some of the samples on the table. These are not the wonderful samples I could show you of doubled-up iron or steel, but that is considered a good practical test for every plate. I am not giving these as specimens of what steel can be brought to, but I asked them to send me stamped as they are, from their great depôt, samples of all the plates they have ever used—half a dozen of each—to lay before you. The letter accompanying these samples tells me that they have got 11,000 of these samples by them, cut from 11,000 plates, worked by the London and North-Western Railway Company into locomotive steam boilers. They tell me that they have at this moment over 300 locomotive engines running and doing their daily and regular work, all built of punched Bessemer steel plates. Not only so, but they are entirely superseding the iron plates which they formerly used, and for which purpose they bought all the best iron that could be bought in the country at the time; and the London and North-Western Railway Company at this moment are making for themselves rather more than six locomotive boilers every six days, so that the average amount of work exceeds one locomotive boiler per day. That is done with punched Bessemer steel plates which our friend the Chief Constructor of the Navy, with fear and trembling, wants us to tickle up with a copper hammer, to bend them a little, and then to bend them again, and to use machinery of that class to make the angle he has described. That is amusing. Now Mr. Barnaby gives us a most extraordinary example of the amount of deterioration which Bessemer steel can undergo, and the amount of ingenuity that has been expended in arriving at that result certainly deserves infinite credit. I need not tell practical men that in punching a hole in a rigid material like steel the grain of the metal in the neighbourhood of that hole is very much disturbed and greatly distressed. The act of shearing, which is quite analogous to punching, also disturbs the grain of the metal. When we have a plate to deal with, either in shipbuilding or in boiler making, of, it may be, 30 inches or 3 feet in width, we have the disadvantage of shearing at those thin edges which go in a quarter of an inch on each side, and those two quarter inches may be deducted from the whole amount of injury done by the shearing. But Mr. Barnaby takes a strip of $2\frac{1}{4}$ inches wide, which has got two shearings upon it, and we have half an inch out of $2\frac{1}{4}$ inches damaged to begin with. Then he takes the thickest of the usual sized plates to stamp a hole through with a punch. To stamp a hole $\frac{7}{8}$ths of an inch in diameter in a narrow piece of metal, leaving only $\frac{1}{16}$th of metal on the side, is to destroy the metal round the hole and to give it no support when punching it through, and, therefore, almost absolutely to destroy it for the time being. Now, that being so, Mr. Barnaby asks us to look and see how much he has been able to destroy it. He has brought it down from 31 to 32 tons in tensile strength to an average of 14·5. He has not told us, as he might

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have done, that if he warmed it in the fire afterwards that 14·5 tons would go back at least to 30 tons. He has not told us the fact that soft iron scarcely deteriorates at all; but it does so, as he says, in the best examples of Mr. Crampton's iron. No doubt he has, with his ingenuity, made better wrought iron than any other man living; but I say it is a known fact that when you anneal wrought iron after punching you hardly restore one atom back again of its original strength. You are asked to judge of the importance of the applicability of steel to shipbuilding from an isolated experiment which never can occur in practice.

Mr. BARNABY: I wish the Meeting distinctly to understand that I had no idea whatever of suggesting that the isolated experiment referred to was intended to be a crucial test as to the value of the Bessemer steel. Bessemer steel has been in use for years; and it was furthest from my thoughts to bring forward that experiment, which was not made by myself, and is interesting only as compared with Mr. Crampton's iron, as a crucial experiment for the purpose of saying whether or not Bessemer steel was a proper material for our use. There are plenty of experiments which we have made, and which I could have given you, illustrating both sides of the question. I must beg Mr. Bessemer not to suppose that I could ever do him, or the beautiful material he has made, so great an injustice as to imagine for a moment that its value would have to be judged by a little trumpery experiment like that.

Mr. BESSEMER: It is very satisfactory to hear that explanation from Mr. Barnaby; but those who look at the printed Paper, and see the tabular form as to Crampton's iron and Bessemer steel, will not probably notice the fact that this was Bessemer steel treated as Bessemer steel ought never to be treated.

Mr. BARNABY: I have said so. My Paper states—"It is not necessary to say to you that Bessemer steel should never be punched without being subsequently annealed."

Mr. BESSEMER: Very well. I need hardly tell you that steel differs from iron from the fact of its being an alloy. We have in many other cases in the arts alloys used which have this peculiarity. We can roll copper red hot with impunity; but if you alloy it with 10 per cent. of zinc, and try to roll it red hot, it tumbles to pieces in the rollers, or so near that point that a touch will break it. Add 50 per cent. of zinc to it, and it can never be rolled cold. We have three useful materials in the arts. We have copper in its ordinary state. We have that valuable metal brass, and the yellow sheathing metal for ships. If you are to judge of the value of brass by the fact that having rolled it hot it would tumble to pieces, or yellow metal which because it was not rolled hot would tumble to pieces, one would come to the conclusion that only copper could be used; but we find these are valuable metals notwithstanding; and their properties and peculiarities being well known nobody injures brass by rolling it red hot; nobody attempts to make yellow metal by rolling it cold; but they are treated in the proper manner, and are never compared with metal which is not treated in a proper manner. Now, if you take steel, which is much more rigid than iron, and will suffer more in punching, it must be annealed after punching; and I am sorry that Mr. Barnaby, notwithstanding his explanation, thought it necessary to put on a printed Paper those two things in juxtaposition, which has reference to the unannealed condition, which is an absurd condition of the metals, and which no practical man would ever attempt to use. That no one should be misled upon the point I have ventured to give you the explanation I have.

Captain SCOTT, R.N.: I look at this subject as a question of construction especially needing the consideration of those who build ships. When steel is struck, it has a great tendency to fly in pieces,

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whether the plates are thick or thin. When it comes to the crucial test of that strongest punch of all, a shot, it invariably breaks up; but wrought iron only rends, and therefore on that consideration alone wrought iron is far more valuable for building ships of war. There is a further point for consideration, which is this—that if you use steel largely inside ships, and a shot were to penetrate and strike the steel it would send innumerable splinters round the ship. How far the same observation applies to a less sharp blow, or a concussion, I will not undertake to say. On the other hand, in considering this question of iron *versus* steel, the Bessemer steel, which we all know is admirable and answers well for most purposes, may not be the best material for shipbuilding. It is not clear to my mind—not that I pretend to understand the matter thoroughly—that an erosive action may not go on in the wrought-iron boiler, which does not take place in steel; and, therefore, if made into a boiler steel may last far longer, its tensile strength being greater. Still it seems to me that Mr. Barnaby has treated steel merely as it relates to shipbuilding, while Mr. Bessemer has spoken of his metal in a more general way as applied to other purposes. Therefore, I do not think what has been said detracts from the merit of a metal, the invention of which is undoubtedly a great credit to Mr. Bessemer, and a great benefit to the country.

Dr. Siemens: There can be no doubt that steel is a metal which is worthy of the highest consideration of shipbuilders, engineers, boiler makers, and all persons, in fact, engaged in construction of that kind. One thing is necessary, namely, that those who use that material should first know what it is. We hear of comparative results of steel and puddled iron as produced in one furnace and another furnace; and one would naturally come to the conclusion that steel was a definite compound varying only as regards quality. What is that compound may I ask? Steel in the form of a needle, an edge tool, or of a punch, is of a hardness approaching that of the diamond; steel in the form of a spring is of an elasticity unequalled by any other metal, or any other substance in nature. Then again steel in the form of a milled plate is, with few exceptions, the toughest material in existence—tougher than copper or wrought iron. It can be moulded into almost any shape in a cold condition. Therefore we ought first to understand what we mean by steel before we consider its merits or demerits for structural purposes. You may say that the hardness depends upon the proportion of carbon in the metal. Does it? I have lately experimented with steel containing four-tenths per cent. of carbon. That steel, if treated in a certain way, would make an excellent punching or cutting tool. If treated in another way, and annealed carefully, it is so tough that you could work it into the form of your hat. Then again drawn into wire and annealed in another way—that is to say, heated to a certain point and then put into oil—it assumes a tensile strength of very nearly 100 tons per square inch; whereas in the other form just before mentioned when annealed carefully its tensile strength would not exceed 35 or 36 tons. Now, if the mere fact of after treatment can produce such enormous changes in the behaviour of steel, how important must it be to give to steel the nature which we desire for structural purposes. Now if you take a plate and throw it down in a wet court-yard, and then punch it and use it for the manufacture of a boiler, there can be very little satisfaction in the result obtained from that material. Very likely in the same plate if you could cut out pieces you would find very different qualities, and some of these qualities would be valuable in one place and would be destructive to the plate in another. It may be laid down as a general rule that a higher material and a higher process requires higher intelligence to deal with it. If you ride a common cart horse, you may go to sleep on him, but if you ride a fine spirited horse all your wits must be about you, or else you may be landed in a ditch. So with steel, you have to understand first of all what quality of steel you have to produce,

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how much carbon and how much manganese should be mixed with the material, and how little sulphur and phosphorus you can put up with. Until you have done that you do not know what you are speaking of. It is a material belonging to a group varying between the hardness of the diamond and the toughness of copper; and it is also of the highest importance that the manufacture throughout, and the construction throughout, should be carried on with superior intelligence. Now should we shrink from using a material because intelligence is required in working and using it? Surely that would be a very poor compliment to this age of progress. We should have no difficulty in finding what are the conditions necessary to produce steel of such and such a quality, and should see to it that we obtain this quality and obtain it always. With regard to the question of obtaining it always, I maintain that we have a greater power in our own hands than with regard to iron: iron, as we know, is produced in small quantities; the puddler produces sometimes a ball which is rather young, and at other times produces it over-heated; and this material is filed again, put through the rollers, and in the end we get a sort of average between the qualities of the different balls. In making steel we formerly dealt with it in small quantities also by melting it in pots, but Mr. Bessemer has first shown us how to deal with it in large quantities in his converter. I have had considerable experience in dealing with it in large quantities in the open hearth furnace. There I know we can produce six, or eight, or ten tons of steel of perfectly uniform quality. We can take out samples before pouring that steel to assure ourselves of having the quality desired. This metal is thoroughly mixed—it is a perfectly fluid mass—and therefore there can be no reason why there should be a difference in the behaviour of one part of this metal from the behaviour of another part. Now I have lately seen steel of a very mild quality produced which is eminently suitable for structural purposes. This steel contains hardly any carbon at all—perhaps one-tenth per cent. only; but it contains manganese in a larger proportion than has been given to it hitherto. It is possessed of a toughness which is unapproached by any other kind of metal; and before it breaks it yields even to 50 per cent. Now if such a material can be produced, and if such a material will resist, say 30 tons, which is quite enough for all purposes, I think that is the very best material for structural requirements.

Mr. Richardson: I should like to make an observation with regard to the two first figures which have been represented on the black board, because I think there may be some misunderstanding existing in the minds of many of us as to those figures. Iron is quoted at Middlesborough at something like £9 per ton, and the iron used by the Admiralty at £20 per ton for the same purposes. I am not a manufacturer but a large buyer of iron, and the difference between £20 and £9 per ton does not really represent the difference in the value of the iron. To a considerable extent, and I think Mr. Barnaby will agree with me in that, it represents the cost to the manufacturer of the Admiralty tests—*the cost of testing the iron to the satisfaction of the Admiralty Inspectors.* It is many years ago now since I had anything to do with the testing of plates by Admiralty Inspectors, and the process then adopted may not be adopted now; but at that time out of thirteen plates of a ship twelve had to be rolled and laid out for the Admiralty Inspector to examine them; they were left so for several days; the plates were then turned over and the other side left for several days to be examined, not by one but by several Inspectors; and if there was a mere flaw—what you might call a mill flaw—on the surface of the plate, that plate was condemned. After that, one of these plates was cut off into strips and tested; and if it failed the whole twelve were condemned. I will not say a word against that practice of the Admiralty, because the more you test them the better iron you get, and to build ships which are to protect our shores the best material should be used. But I would point out that that

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system of testing is one that cannot be adopted in commercial transactions. It is impossible. You have not people you can rely upon to do it. That being the case, there is another kind of test adopted. Speaking as a shipbuilder, I think if I go to a respectable firm of high standing to buy plates the following tests may be relied upon. In the first place, I expect that that firm, probably working its own ores, will see that they are carefully selected, and that, when the pig iron comes out from the furnace there will be a careful examination which will show at once whether it is right or wrong. Then the foreman tests it to see whether it is good. It is rolled into puddle bars, and the mere appearance of the puddle bars shows whether the iron is right or not. Those puddle bars are cut up and other processes are gone through until it comes to us in the form of a plate. In the form of a plate it is sheared and punched, and a practical eye can see at once whether it is good or not. And that iron quoted at Middlesborough (which some gentlemen in the room speak of as ship-sinking iron) is expected by people who buy it to stand what may be called the flanging Admiralty test. If we are building a ship, can we expect, without paying anything extra for the plates or without specifying the purpose for which those plates are to be applied, that every plate shall bear that test, and that if it does not bear the test the manufacturer will give us a new plate and pay all the cost of carriage both ways and all the cost of labour? I do not wish to say that the test I have mentioned is as good a test as that adopted by the Admiralty; but if the plates can stand all that, we can get some very fair iron, and very reliable iron, which is the main point. A ship that I built lately, called the *Clive*, struck upon a reef in the Red Sea, and for half her length amidships there was not a plate that was not seriously bulged. She was put into dry dock; every plate was taken off, heated and strained and put on again; and I say if merchant ships can be treated in that way the iron cannot be very bad. I should like to say something about the Crampton process. Gentlemen who are interested in that process must not shut their eyes to the fact that it is wanting in that particular test which common merchant iron has. It does not go through the various processes: it is one large mass, and you do not know what it is. There are gentlemen present interested in steel manufacture who have spoken about steel; but what Mr. Barnaby has said in his Paper is simply correct. We have all burned our fingers in touching steel, and it may be for want of that high intelligence which Dr. Siemens spoke of in ourselves or our men. We have got very serious responsibilities to undertake, and must be very careful indeed what we are doing. The first steel plate that I had to do with was a Bessemer steel plate in the sense that it was manufactured by the Bessemer process. You could bend it over cold, and it was used as a top plate for a boiler flanged in the fire. I do not know whether it was properly annealed or not—probably not, but it was drilled and laid down carefully, and in laying it down it broke in two. The object of my remarks is to draw attention to the fact that the difference in the price on the black board does not represent a difference in the quality of the iron, but the cost of testing it according to the Admiralty practice, and the cost of replacing what is condemned in those tests.

Colonel CAMPBELL, R.A.: Mr. Barnaby clearly admits that such steel as he requires is not in the market—that is, steel at a fair price and of a quality suitable for shipbuilding. The only character or description of steel at all likely to be suitable for shipbuilding would appear to be that employed for gun tubes—that is, a steel approximating to wrought iron. All our gun tubes are made of crucible steel (for which, of course, a large price is paid), and blocks of nearly 18 tons weight have been so produced. This steel answers well for the interior of guns, and appears to possess the conditions and characteristics required by Mr. Barnaby, so far as we can judge from our experience with our gun blocks; but whether these

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qualities would obtain when this description of steel was reduced into plates is a matter that could only be determined by long and costly experiments, and even then the expense would almost amount to a prohibition of their use. Whether the required conditions can be realised by the Bessemer or open bath processes, and at prices ranging much lower, remains an open question. It appears to me that Mr. Barnaby in his Paper has spoken from an experience of questionably made iron; that is, iron plates, piled or composed of numerous layers, almost necessarily implying defect. If the efforts of individuals had been to improve wrought iron, there would, by this time, have been a higher standard of wrought iron for him to compare with steel. Inspection should begin, not after the plates have been produced, but in the preliminary processes—in the pig, the puddling, piling, and rolling, not omitting the heating. If plates were inspected during all these processes a very much higher quality of iron would be obtained. In the gun factories the difficulty of obtaining wrought iron from the trade to meet our tests rendered it necessary to put up puddling furnaces, and manufacture bar iron for ourselves. I believe Mr. Crampton's process is in the right direction, inasmuch as it possesses the homogeneity of steel with the ductility of wrought iron. Plates made from this system direct from a bloom would be without laminæ, and might probably meet Mr. Barnaby's requirements. Mr. Bessemer has stated that at the London and North-Western Railway Works at Crewe, steel made by his process is largely used for boilers, &c., and I can only say the manager of the works is a very bold man, but he certainly takes the greatest pains to test his material during all stages of manufacture, and the material is made under his own eye. He appeared, however, to be using the open-bath process as well as the Bessemer, and with as good results.

Mr. Wilson (C. Cammell & Co., Sheffield): I should like to give my views on Mr. Barnaby's Paper, because I am a manufacturer both of iron and steel, and my views will be those of the manufacturer. We have made large quantities of iron for the British Admiralty, and while the value of the iron made under the Admiralty conditions and specification is no doubt somewhat enhanced by the cost of carrying out the many tests required, the quality of the iron plates secured under these tests is such as in almost every respect to equal the best Yorkshire irons; so that, quality considered, the Admiralty iron is purchased at moderate rates, and as regards price cannot fairly be compared with the ordinary Cleveland or other ship plates. We have also made very large quantities of Bessemer steel for every purpose. Perhaps we are amongst the largest of the producers of Bessemer steel in this country. My experience has also extended for many years to the manufacture of every class of steel by the crucible, and also by the Siemens-Martin process. Reverting first of all to the Bessemer steel, and to the reflections which Mr. Bessemer seemed to think had been cast upon it by the Paper just read, I would mention that twelve years ago, shortly after the introduction of the Bessemer process, I was about the first to use steam boilers wholly made from Bessemer steel. There were seven Cornish steam boilers put down in our works, each of them 8 feet in diameter, 30 feet long, with two flues in each. While these were being constructed, and at the time of applying the hydraulic test which was stipulated, one plate of the first boiler broke from rivet hole to rivet hole across the plate. That was replaced by another, and at the second test of the same boiler another plate gave way in a similar manner. That was again replaced, when the boiler stood the test. The second boiler suffered similarly, when the makers, feeling their responsibility in the matter, told me I had better make them all into water tanks rather than use them as steam boilers. I persevered, and the whole seven boilers were ultimately finished, and put down in our works, and worked at 70 pounds steam pressure. They have been working for nearly twelve years under that pressure, and I believe them

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to be practically as good boilers to-day as ever they were. But in respect to Bessemer steel plates there is this difficulty—the want of absolute uniformity—notwithstanding the use of the same materials and fuel in each "blow," the product of each blow is not always the same. No doubt much has been done in late years to secure a more thorough control over the process of manufacture, and better results as a rule are obtained under the experience of the past ten years; but we cannot yet say that Bessemer steel plates can be treated without extreme care in working them into structures. Excellent material is made by the Bessemer process, but what is particularly wanted is a soft steel plate perfectly homogeneous and uniform throughout. The problem which Mr. Barnaby requires to be solved is this—he wishes to have steel plates upon which he can depend in every way as he can depend upon the best irons; that is, that they may be roughly treated without being liable to fracture like glass, and will at the same time meet all the conditions of the Admiralty requirements—something like a tensile resistance of 27 to 30 tons per square inch, with an elongation of 22 per cent. to 25 per cent. I have worked at this problem for some years, and I think we have got near to the point of success if we have not already reached it. I have brought specimens here to-day, and have made many experiments, so that the Members may see from them the nature of this material and judge of its strength and character. The price of this steel does not greatly exceed that of the highest grades of the Bessemer material. Mr. Barnaby has referred in his Paper to the strengths of Bessemer steel and the Crampton iron when punched. The following is the result of the steel to which I refer:—A $\frac{3}{8}$-inch plate, 2 inches wide, with a $\frac{3}{4}$-inch rivet, gave—

	Strength of the Material between the holes, per square inch. Tons.		Elongation in 6 inches. Inches.	
Cammell's Sub-carbonized Steel	23·8	... ...	·29	
	21·18	Mean, 22 086 tons. ...	·28	Mean, ·29 inches.
	21·27	... ...	·3	

N.B.—The holes after being punched were left untouched, and the material left unannealed subsequently to punching.

The limit of elasticity of the steel used in these experiments averaged 16·96 tons per square inch crossways and 16·18 tons per square inch lengthways. The ultimate breaking strain averaged 29·56 tons per square inch crossways and 28·94 tons per square inch lengthways. The elongation averaged 20·97 per cent. crossways and 23·82 per cent. lengthways. The angles through which this steel bent when cold without fracture averaged 120° crossways and 180° lengthways. If this material can be made in large quantities, and I believe it can be made, it is the material which the British Admiralty are in search of, and which will be eminently suited to the construction of ships, steam boilers, and other structures, inasmuch as while it is perfectly homogeneous, it tears as iron does when the point of fracture is ultimately reached, and can be treated in all respects as iron in making it up into the varied forms required.

Mr. MARTELL: I think all those who have had to deal with the troublesome question of the quality of iron will agree with Mr. Barnaby, that credit is due to the Admiralty for the firmness with which they have carried out the Admiralty tests on iron. I have no hesitation in expressing my opinion that it has given a tone to the whole manufacture of iron, and kept up the standard of iron ships, and the standard of iron. Had it not been for that, the quality of iron would have been at this time very much worse than it is now, and I do not think it is quite in such a satisfactory state now as Mr. Richardson seems to think. That is my experience of it. I may add much is due to the Admiralty for what they have done to improve the quality of workmanship in iron shipbuilding. We know more than one large yard in which, previously to the building of Government ships in them, the workmanship was of an indifferent character;

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but the amount of supervision which the Admiralty insist upon, the number of inspectors they appoint to each ship, and the manner in which shipbuilding operations were conducted under their supervision, produced a good effect among the men as well as the officers, and got them into more careful ways of doing work. The close inspection undoubtedly produced a very beneficial effect; and the workmen employed on these Government ships, being of migratory habits, going from one yard and from one port to another, have tended sensibly to improve the whole system of shipbuilding and workmanship throughout the country. Therefore, I think the Admiralty are certainly entitled to credit. With reference to the remarks that have been made on steel, my experience teaches me that Mr. Barnaby is perfectly right in his observations. We have seen a great deal of the use of steel, both in the manufacture of it and its use in ship-yards; and it is of not so reliable a character that we like and can depend upon. That it has not been more employed may be greatly due, no doubt, to the want of that care which is necessary in such a delicate material as steel. That care cannot be exercised in ship-yards; shipowners and shipbuilders do not and will not exercise the careful supervision which alone can make it safe to employ steel; they cannot ensure that all the plates after they are punched are properly annealed, neither can they see that they are not subject to concussions, and consequently they cannot deem it of that reliable character that would recommend it for general adoption. But there is another important element with regard to the use of steel that always interferes very materially with its adoption for mercantile purposes, and that is the great comparative price. If we take, for instance, a ship of 1,000 tons, and say roughly that the iron in that ship would weigh about 500 tons, and take the price roughly at £8 10*s*. per ton, the material would cost £4,000 or £4,500. Then allowing for a deduction of one-fourth, which the Committee of Lloyd's Register allow for the adoption of steel instead of iron—and I do not know that a greater reduction has been advocated (and it is not only a question of tensile strength, but the plates must be retained of a certain thickness to prevent buckling)—if you adopt that one-fourth less, the quantity of iron in that case would be 350 tons instead of 500. That you will find would cost double as much as the price of iron, and the mere fact of carrying 150 tons more cargo would not repay the shipowner for going to such a great amount of additional expenditure; and, therefore, the price of steel must be very materially reduced, even if it be made more reliable than it is at present, before it can be largely adopted in mercantile shipbuilding.

Mr. Thornycroft: I should like to make one or two remarks in defence of steel. It has been alleged that steel is not a reliable material, and that iron is. I beg to ask iron manufacturers and the manufacturers of the best Yorkshire iron whether they can make reliable boiler plates? I had occasion to return boiler plates to Yorkshire that would not stand punching anywhere near the edge without cracking. I have seen Bessemer steel plates punched so near the edge that only a shred of steel remained, as thin as cotton, without breaking. I would submit that iron can scarcely be made of that quality, and I have seen many hundreds of plates of steel stand that test without fail.

The Hon. Arthur Duncombe: I did not come here at all prepared to address this Meeting, but I should like to say a few words on the question of steel. In the admirable address we have had from Mr. Barnaby he has stated what are our prospects of obtaining a material which we can use without such delicate manipulation, and without so much fear and trembling as has been referred to. I am referring to the manipulation which has been found necessary in building war ships in France. There is a small Company which I think it is not too much to say has almost solved the difficulty. The country is

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indebted to Mr. Bessemer for inaugurating the immense strides which we have made in steel making, and the process I allude to starts from his process, and his converter is used. But in this question all rivalry should be put aside, or at all events should be of a friendly character; and I think he will not be offended if I say we have gone a step beyond him. This material, which seems to answer all the objections made to Bessemer steel, can be made of perfectly uniform quality. It requires no more skill and management than any intelligent workman or foreman can bring to bear upon the subject, and the cost of it is not beyond that which is reasonable. I have here some specimens which I should be glad to submit to any gentleman who would like to inspect them, which have been hammered cold under an ordinary steam hammer without the slightest difficulty into this shape. That is not of great thickness—a quarter of an inch. This specimen, [*exhibiting it*] three quarters of an inch or rather more in thickness, was hammered cold under a steam hammer, and rendered flat by terrific blows, and there is not a scratch or mark on it. If what I have said can be proved, which it can be without the slightest doubt (and I shall have the greatest pleasure in taking any gentleman down with me to Birmingham and showing him the metal which has been made), I think it will be seen that that material meets all the requirements that can be asked of steel or metal makers. The metal is not only suitable for boiler plates, but also for ship plates and angle irons; and, as I said before, the prices are not such as to preclude its use. There is another quality which I should like to mention which is evident to anybody who examines the metal, namely, its extreme ductility.

Mr. J. Scott Russell, F.R.S.: I have one word to say which is, as a shipbuilder and therefore concerned in keeping up the honour of English ships, I am glad Mr. Barnaby has had the courage to back our Admiralty in giving a contract to ironmasters of the best character and for the best iron, instead of at the lowest price. I hope you will all support me in that opinion. We are degenerating every day by giving the contract to the cheapest tenderer. If there be anybody in the world who ought to help to maintain the standard of English character it is the Admiralty; and it seems to me that what they should do is this: they should give some of their contracts to different people at a price fixed by themselves, and then they ought to give further contracts, not to the men who offered the cheapest, but to the men who, for a given reasonable price, gave the best material and the best work. I hope, therefore, you will not be angry that the Admiralty give a good price for good iron, but I think we should be very angry with them if we found that they gave the price of good iron, and then took bad. Therefore if the price they give be better than other people give, they ought to insist on the iron they get being better than other people's iron.

Mr. Barnaby: I need not occupy the time of the Meeting more than a minute or two in reply. My brethren in the profession, shipbuilders and marine engineers, have, I think, answered some of the hard things which Mr. Bessemer said. I am sure it was farthest from my thoughts in coming here to depreciate unduly Bessemer steel. I want just to say this—that we have been using Bessemer steel in every iron ship built for the Navy for years past, but we never use it without fear and trembling. I have here a piece of it which was made by one of the best firms in England, whose name I will not mention, for a ship now in course of construction. You will observe that this piece of steel bends beautifully on the one side, but you will see also how it is broken on the other. That was broken under the ordinary test to ascertain whether or not it would stand the bending angles. I say that material is a material which we are forced to look at with a very great deal of suspicion indeed.

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ON SPAR TORPEDO WARFARE.*

By A. Sedgwick Woolley, Esq., Secretary, Associate.

[Read at the Sixteenth Session of the Institution of Naval Architects, 19th March, 1875; Joseph Woolley, Esq., LL.D., F.R.A.S., Vice-President, in the Chair.]

Spar torpedo launches are being so generally adopted at present into the service of all foreign nations, that a short sketch of the origin and history of this form of submarine warfare may be interesting, before discussing the merits and demerits of the plans now in vogue.

The first idea of an offensive attack by means of a boat specially constructed to carry a torpedo seems to have originated with Captain David Bushnell, of Connecticut, about the year 1775, but it had little in common with the boats now used for the same purpose. This boat, an account of which was read by the inventor before the American Philosophical Society in 1798, was only intended to accommodate one person, who sat in a water-tight chamber capable of containing sufficient air to support him for thirty minutes, and who could cause the vessel to descend and ascend at will by letting the water into a chamber below him, or expelling it therefrom by means of two brass force pumps, at the same time letting fall about 200 pounds of the lead by which the vessel was ballasted at the bottom. The boat was propelled by an oar and guided with a rudder, and had an iron tube fixed to its crown capable of sliding up or down through a space of 6 inches. A rod passing through this tube carried a wood screw which could be fastened into the bottom of a ship by turning the rod, and then cast off by unscrewing the rod again. A rope was extended from this screw to a torpedo, placed on the top of the boat, which could also be cast off in a similar manner, and thus left hanging below the ship. The torpedo was fitted with a clock which could be set so as to release a lock after any given time and fire the powder. An attempt was made with this boat to blow up the English sixty-four gun ship *Eagle* during the campaign of 1776, but the operator from some reason or other was unable to fix in the screw and had to desist from the attempt. Soon after this, the ship on which the torpedo boat was carried was sunk by our guns, and no other boat was built at that time on the same principle.

* Received 16th March, 1875.

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The next step in the same direction was made by the celebrated Fulton, who proposed a similar diving boat to the French Government about the year 1801, and made several successful experiments in the harbour of Brest, blowing up a small vessel by means of a torpedo, which he placed under her bottom. In this boat Fulton seems to have employed a screw, operated by a crank, as a means of propulsion. The French Government, however, would not adopt his invention, and Fulton forthwith withdrew to England in 1804, where, under the assumed name of Francis, he obtained the support of Mr. Pitt. A Commission was appointed to examine into and report upon his invention, which it at once pronounced to be impracticable. Fulton then returned to America, where he also gained the ear of the Minister, and had a Commission appointed, but he met with such great opposition, and was so unfortunate in his experiments, that he gave up the attempt to introduce a system of torpedo warfare in order to turn his attention to steam navigation, which he may be said to have introduced into that country. It may be remarked, however, that during the course of his torpedo experiments he developed the first notion of the torpedo steam launches of to-day. This idea, which never got beyond the state of a model, consisted of a vessel of 300 tons, shown in Fig. 1 (Plate VI.), with sides 6 feet thick, designed to be cannon proof, and musket-proof decks 6 inches thick. She was to be propelled by a scull wheel, and was intended to carry two torpedoes on each side, fixed on the end of spars 96 feet long, supported by guys from the masthead. Another diving torpedo boat, very similar in construction to Bushnell's, but capable of accommodating a crew of nine persons, and carrying a torpedo at the end of a spar, was attempted to be used in 1813 against the English fleet off New London, but without success, for while proceeding to the scene of action she went ashore, and was blown up by her own crew to prevent her being captured.

Stationary torpedoes were employed during the Crimean War for the defence of Sebastopol and Cronstadt, but the Russians, probably deterred by the ill success of all former offensive torpedo boats, did not attempt any trials with them, and it was not until during the Civil War in America, when the Southern States, being overpowered by the force and resources of their adversaries, resorted to a most extensive employment of torpedoes, that the power of this species of attack was developed.

The first of these attacks was made off Charlestown, against the U. S. war vessel *Ironsides*, by a cigar-shaped boat under the command of Lieutenant Glasselle, with a crew of three men, carrying a torpedo containing 60 pounds of powder at the end of a spar. Not knowing the action of the explosion, and thinking that their boat would probably be sunk by it, her crew jumped overboard before ramming. The explosion, though severe, failed to effect any hole in the bottom of the *Ironsides;* the boat was also

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uninjured, and was found drifting half full of water by her engineer, who climbed into her, made up his fires, and steamed back safely to Charlestown.

The next attempt was also made off Charlestown with a plunging boat against the U. S. steamer *Housatonic*, which was sunk by the explosion, the torpedo boat, however, going down as well. This boat had already drowned sixteen men during the trials made with her in Charlestown Harbour, the last time going down with a crew of nine persons, and not again appearing till she was fished up and put in order, when a fifth crew of six persons, under a Captain Dixon, undertook the attack on the *Housatonic*. She was propelled by means of a screw worked by a crank, which required the six men, sitting three and three opposite each other, to turn it. The *Memphis* was then attacked, but unsuccessfully, a heavy rifle fire being opened from her upon the attacking boat, which was thus forced to beat a retreat. A most courageous and gallant attack was next made on the *Minnesota*, by Captain Hunter Davidson, who with two companions in a small ordinary steam launch started one evening from Richmond, and steamed down to Newport Roads, a distance of about 160 miles. Remaining the whole of one day up a creek under shelter of some bushes—from which position he could see the Federal gun boats passing to and fro along the river—and starting again at nightfall, he arrived in the midst of the enemy's fleet about 2 a.m. Here he found that the vessel he intended ramming was surrounded with coal barges, so he attacked the flag ship, the *Minnesota*, striking her with a torpedo, containing 53 pounds of powder, on the end of a spar inclined at an angle of 30°. The explosion took place in wake of the magazine; but, as it appears, the *Minnesota* was at the time carrying a large quantity of shot and shell for the use of the army, which were stowed down low in her bilge; and their great weight must have resisted the explosion, for otherwise 53 pounds of powder ought to have made a hole in a wooden ship. Although this attempt was made in the centre of the Federal Fleet, Captain Davidson got away in spite of a heavy fire which was opened upon him, and steamed safely back to Richmond. Numerous other attacks were made with similar boats, but without success.

The Federals, at last, also took to the use of torpedoes; and the Confederate ship *Albemarle* was sunk by a torpedo launch, commanded by Lieutenant Cushing. The launch, however, was also sunk by the explosion; and, out of a crew of fourteen persons, only two saved themselves by swimming. Both sides were employed in preparing special spar torpedo boats when the war terminated. Just before the close of it, however, a remarkable attack was made, in the James River, on the merchant vessels which had brought supplies to Grant's army, by the Confederate fleet of three iron-clad rams and seven gunboats, all armed with torpedoes, fixed on the end of spars, 30 or 40 feet long, which projected from their bows, and could be raised or

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lowered by a tackle. This fleet was stopped by a boom, and two of the iron-clads got aground, where they remained all night, under fire from the banks; but, although their torpedoes were completely riddled with rifle shot, not one was exploded, as it so happened that the fuses were in no case struck. The Southern States had throughout employed percussion fuses, which were exploded on contact, the shape of their torpedoes being cylindrical with hemispherical ends, into which seven fuses were inserted, as shown in Fig. 2; these fuses (shown in Fig. 3) consisted of a cap of lead *a*, containing a glass tube *b*, filled with sulphuric acid, and surrounded with a mixture of chloride of potash and white sugar *c*, communicating with a primer *d* of mealed powder; on contact, the lead cap being crushed, the glass bottle was broken, and the sulphuric acid ignited the chloride of potash and sugar, and fired the torpedo. The danger of a torpedo, furnished with these fuses, being exploded by contact with any floating log of wood or boom, before reaching the enemy's ship, and the extreme caution required in handling it, led the Federals to adopt a torpedo made as shown in Fig. 4, which could be detached from the spar, and was provided with an air chamber to keep it nearly vertical when so detached, a tube being placed in its centre, at the upper end of which an iron ball was kept in position by a pin; this pin was released by means of a rope, leading into the boat, and the ball then dropped on a cone of fulminate.

But as it has been found that, unless the torpedo is actually in contact with the side of a vessel, there is a great chance of the explosion failing to blow it in, since it will always take the line of least resistance, the plan of firing at will has the disadvantage of being left entirely to the discretion of the operator, who, in the darkness of the night, under cover of which these attempts have to be made, may easily miscalculate the distance he is from a ship, and so fire his torpedo too soon. To obviate the evils of these forms of fuses, Captain McEvoy, of the London Ordnance Works, who has had great experience with the contact torpedo system of the Southern States, invented the mechanical fuse A, shown in Fig. 5, provided with the safety cap B; but being afterwards impressed with the advantage arising from the use of electric communication, he invented, in 1871, the plan shown in Fig. 6. This consists of a metal bushing *a a*, having its upper end closed by a thin metal dome *b*, and a metal plug *c* screwed into its lower end. A metal spindle *d* is supported on a spiral spring *e*, inserted in a recess *f* in the plug *c*; a thin insulated bridge *g* is attached to the spindle *d*, under which are two terminals *h h* of insulated wires *i i*, one of these wires being connected with the battery, and the other, to which is attached the electric fuse, having either an earth or other connection with the battery. When the torpedo with this closer attached is projected against a vessel or other body, and receives a shock sufficient to crush in the thin metal dome *b*, the spindle *d* is forced down until the metal bridge *g* is brought

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into contact with the two terminals *h h*, thus completing the circuit of the electric fluid, and firing the fuse. The wires would, of course, only be connected to the battery just before the action of ramming. It is, however, evident that the thin metal dome might be crushed in through some accident beforehand, and that then, as soon as the wires were connected, the torpedo would be fired at once. To overcome this difficulty there has been substituted for the metal dome *b* one made of india-rubber, fixed in a peculiar manner, which would always retain its form and allow the spring *c* to keep the circuit uncompleted.

The torpedo is shaped as shown in Fig. 7, in order to insure the contact of the fuse with the vessel. Still it is apparent that cases might arise—such as in striking a vessel under the counter—where the closer might not operate. In such cases it is very desirable that it should be possible for the operator in the boat to have the power of firing the torpedo at will. To effect this it would seem to be necessary to have a second fuse and two more insulated wires; but as mistakes might arise from unskilfulness on the part of the operator, and the wrong wires applied to the battery, and the torpedo thus be fired before contact, this plan has not been adopted. Captain Mc Evoy has, however, invented a fresh method, whereby with a single platinum fuse and battery, and one set of wires, the torpedo can be fired either on contact or at will.

The system of firing shown in Fig. 6, is that generally adopted with the torpedoes to be used with the launches which are being at present built for foreign countries. The launches may be divided into two classes, *viz.:* those intended for river service, and those meant for ocean purposes. Fig. 7 represents a river launch similar to those constructed by Messrs. Yarrow and Hedley, of Poplar. The one shown is 45 feet long and 7 feet 6 inches beam, calculated to have a speed of 14 knots, built either of iron or steel, the plating being $\frac{1}{8}$ inch at the keel, and $\frac{3}{32}$ inch at the gunwale.

The draught is 3 feet 6 inches, and her freeboard 2 feet. There is a steel turtle-back shield forward full $\frac{1}{8}$ inch thick, to afford protection to the men and steering wheel, and to throw off the water which might come on board from the explosion of the torpedo. The engines and boilers are also provided with steel sliding covers. The boilers are locomotive, with a total heating surface of 140 feet, the barrel plates being $\frac{1}{4}$-inch Low Moor iron throughout, with $\frac{3}{8}$-inch butt straps inside and out, double riveted, and the engines non-condensing direct-acting of 55 horse-power, working up to 140 pounds pressure. The diameter of cylinders is $6\frac{1}{2}$ inches, and length of stroke $7\frac{1}{2}$ inches. The frames are made of 1-inch angle irons with $\frac{3}{4}$-inch reverse irons.

The spar *c* for the torpedo is shipped amidships, and can be run out over the roller *e*. A pocket *a*, suggested by Captain Davidson, is provided to allow the spar to

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have a greater depression than in the old plan of running it out over a roller on the top of the stem. Two stanchions *f* provided with pin holes allow of the spar being depressed through an angle of 35 degrees, a noiseless exhaust chamber *k* preventing the approach of the boat being heard. In this chamber the condensing is effected against a portion of the skin of the boat, the plates there being increased in thickness. It is surprising what a small effectual surface is required to condense the steam in cases where the object is simply to condense it in order to avoid the noise, or to get the fresh water back into the boiler, and not with the object of obtaining a vacuum.

The boats built by Messrs. Yarrow & Hedley for ocean work, and intended to be navigated in any weather short of an absolute storm, are made on exactly the same principle but with larger scantlings and a greater draught and height of freeboard. The one at present building for the Dutch Government is 66 feet long, 10 feet broad, and 5½ feet deep. She has a pair of direct-acting inverted engines of 200 horse-power, working up to 130 pounds pressure, diameter of cylinder 11 inches, length of stroke 14 inches. The boilers are locomotive, with 450 feet total heating surface. It is proposed to fit this boat with a small auxiliary donkey engine to facilitate the working of the spars. Those, however, constructed by Messrs. Thornycroft & Co. (shown in Fig. 8), are completely covered with a steel deck $\frac{3}{16}$ inch thick over the central portion, and have bottom plating $\frac{3}{32}$ inch thick. They have surface condensing engines and are fitted with Messrs. Thornycroft's new patent screw propeller. The one just finished for the Swedish Government is 58 feet long, 7 feet 6 inches beam and 3 feet draught, and with an average number of 505·48 revolutions per minute obtained a mean speed of 17·27 miles per hour.

In our own Navy we have not as yet built any special torpedo launches; it being considered that it would be quite sufficient to fit up ordinary ship gigs and launches for this service. The method of fitting these launches hitherto used has been to cover the fore part of the boat with a canopy of canvas, and to work the torpedo spar on outriggers placed on either side of the boat, and to rig it out and in by means of a rope worked from the stern sheets, another rope being attached to the heel of the spar to ease it out and rig it in again.

We have also adopted the electric method of firing at will, and not by contact; but as has before been pointed out, in actual warfare, when attack is made under cover of darkness, it is a very difficult thing to judge exactly when to fire the torpedo; and if the approach of the boat were perceived, as in the majority of cases happened in the American Civil War, she would be met with a fire of small arms, against which the canvas cover would be no protection, and it would be doubly difficult for men in danger

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of being shot down every moment to keep cool enough to judge accurately the exact moment when to fire the fuse. An expedition with a spar torpedo boat will necessarily always be one of extreme danger, and partake of the nature of a forlorn hope; and it seems but right that everything should be done in such cases, not only to provide every element of success practicable, but also to protect as much as possible the lives of the volunteers who venture in such a service.

Lieutenant-Commander Barnes, in his *Submarine Warfare*, lays down the following as the requirements of a torpedo boat:—

"1*st.*—She should be swift, easily managed, and capable of being turned rapidly in "obedience to her helm.

"2*nd.*—She should be practically invulnerable, and should expose as small a surface "as possible to view.

"3*rd.*—Her machinery should be noiseless, and be capable of discharging any "number of torpedoes in succession in any direction from herself.

"4*th.*—She should be completely covered so as to render swamping impossible.

"5*th.*—Her torpedo arrangements should be such that contact of the vessel or the "torpedo with the ship attacked would be unnecessary.

"6*th.*—She should be devoted solely to torpedo warfare."

If we examine into these six supposed requirements in detail we shall find that some still hold good, others have been rendered impossible by the changes which have taken place in our artillery, and one or two are still moot points on which different opinions are expressed.

I think every one will allow that the first condition of speed and rapid manœuvring admits of no dispute, for the quicker one of these boats can dart out from the shelter of a bank or ambush and approach her adversary, the more likely is she to escape observation. This also takes in part of the third condition, *viz.*, that her machinery should be noiseless, which is now obtained by means of the exhaust chamber.

As to the second condition, "practically invulnerable" is now absolutely impossible. This was attempted in the American torpedo boat *Spuyter Duyril*, with 5 inches of armour, and a draught, when equipped, of 7 feet 5 inches; but the size of our guns has increased so much, that sufficient armour to afford protection against them would necessitate so deep a draught as to render the torpedo boat useless in rivers navigable by light-draught gunboats, which, however, carry heavy guns. What seems really to

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be required, in combination with quick action, is protection to the crew from rifle shot, and in this case our canvas cover is useless. It might, however, be easy to provide a portable cover of boiler iron, capable of being fitted to the fore part of the boat in a few minutes, if the boat itself were in other ways suited to the purpose.

The fourth condition was probably laid down owing to the few data existing, at the end of the American Civil War, as to the effect of the explosion of a torpedo. It has now been proved, that, with a spar 25 to 30 feet long, a charge of 100 pounds may with safety be exploded at a depth of 10 feet, the radius of explosion being only about 9¼ feet.

With regard to the fifth condition, I have already pointed out how necessary contact seems to be; for nothing but simple and absolute contact can insure in all cases the torpedo being exploded within sufficient range to effect serious damage to the vessel attacked.

The sixth and last condition is still a moot point, but there is no doubt that it may be practicable to provide ordinary steam launches with fittings capable of rendering them efficient torpedo boats if required; though in this case it must not be forgotten that speed, noiselessness, and protection from rifle shot are three indispensable requirements.

DISCUSSION.

Mr. J. Scott Russell: I think we must all agree in thanking Mr. Woolley for his very interesting Paper; but I do not fancy that any observations of ours would improve the torpedo. As he was reading the Paper I was thinking how we should disimprove the torpedo; and I think I see how we might send a little launch along with the ship that would rather astonish that torpedo boat.

Mr. Henry Liggins: I think it is very encouraging to naval architects to find that the necessity of the service requires boats of great speed of such small size. It is quite a novelty. It is only within the last few years, since Mr. Thornycroft was good enough to read his Paper on the subject of fast steam launches, that such a speed as 17 knots an hour has been obtained. I think it is very encouraging to know that naval science has arrived at such a state of excellence as that when there is a demand for a thing the skill and genius of the country is able to produce it.

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ON A NEW BINNACLE INDICATOR.*

By the Right Hon. Viscount Bury, K.C.M.G.

[Read at the Sixteenth Session of the Institution of Naval Architects, 19th March, 1875; Joseph Woolley, Esq., LL.D., F.R.A.S., Vice-President, in the Chair.]

1.—The instrument which I venture to submit to your notice I have called "Bury's "Binnacle Indicator." Its use is to show, without calculation or delay, the approximate course which any vessel is steering whose lights are observed from the deck of your own ship at night.

2.—I believe that the indicator may be useful in diminishing the risk of collisions between ships at sea.

3.—The indicator (Fig. 1) consists of a strap or collar of brass fixed on the outside of the binnacle, and capable of moving freely round it. It thus surrounds the binnacle compass, which must be concentric with it. The indicator must not, however, touch the compass, in order that the latter may be perfectly free to oscillate. Fig. 1 shows the indicator fitted to a ship's binnacle. It may be fitted either as a collar or a simple disc to a binnacle of any shape. A is the knob by which the collar C is turned. B the lubber point which is brought on to the compass bearing of the observed light.

4.—The indicator is painted thus: Through an arc equal to 12 points of the compass, white; then through an arc of 10 points, green; and again through an arc of 10 points, red. In the middle of the white segment is a lubber point painted half green and half red. The red colour being in each instance to the right hand of the spectator looking at it from the centre of the circle (Fig. 2). Fig. 2 shows the indicator in use. C is a ship with her head N.N.W. The wind ←—— is at W. by N. C sees a red light D, four points on her own starboard bow, *i.e.*, N.N.E. The officer or look-out man seizes the knob A of the indicator, and brings the lubber point B on the compass bearing of D. The indicator shows that D is steering between N.W. and S.S.W., and the wind being W. by N. shuts off all except from S.W. to S.S.W., the limit (E) of D's course.

* Received 19th March, 1875.

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5.—To make my remarks intelligible I must say a few words about the rule of the road at sea.

6.—Every ship is bound to carry a green light on her starboard side, and a red light on her port side. These lights are to be so screened as to show from right ahead to 2 points abaft the beam, that is through 10 points of the compass. Steamers carry in addition a white light at the mast head.

If the green light of one ship is opposed to the green light of the other, those ships will go clear, or if the red light of one is opposed to the red light of the other they will go clear. They are passing left hand to left hand or right hand to right hand. If, however, lights of opposite colours are opposed to each other, those ships are crossing in such a manner as to involve risk of collision.

7.—The cases in which risk of collision is involved may be reduced to three:—

1.—Ships meeting end on.

2.—Ships crossing to port.

3.—Ships crossing to starboard.

The rules affecting these cases are modified by the question whether the crossing ships are:—

1.—Two steamships.

2.—Two sailing ships.

3.—A steamship meeting a sailing ship.

The case of sailing ships is complicated by the consideration that the wind shuts off 10 points of the compass out of 32; in other words, that ·33 of the whole circumference of the horizon is closed against the sailor, and any direction within the segment so closed is not available for escape from collision. Owing to this circumstance the rule of the road has to be so modified that the duty of a sailing vessel is often exactly the reverse of what would be the duty of a steam vessel under similar conditions.*

8.—The binnacle indicator, as I have said, comes into action when the lights of a crossing vessel are seen from the deck of a ship at night.

Its use is to tell without calculation or delay the direction in which such crossing vessel is steering.

* For example (*see* Fig. 5). *Sailing Ships.*—Sailing ship A. Head N. Wind E.S.E. Green light B two points on port bow, *i.e.*, N.N.W. It is A's duty, being weathermost ship (both being on starboard tack) to keep out of the way (Art. 12). *Steam Ships* (under same conditions).—A's duty is to hold on; because a steam ship having another on her own starboard bow, shall keep out of the way (Art. 14), and A is on the starboard bow of the crossing ship B.

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9.—By day the mariner can see this for himself. He can see at a glance, by the direction of the crossing ship's head, and by the set of her sails, whether she is on the port or starboard tack, whether she is close hauled or running free, and whether she will go clear of his own ship or not. Having this knowledge, he at once remembers, or ought to remember, the particular article of the "Rule of the Road at Sea" which applies to his existing circumstances.

10.—By night this cannot be the case. The only thing seen is a green or red light, or both together, with or without a white light over them. The hull and direction of the vessel is invisible. The rest is a matter of calculation.

11.—The rule for performing that calculation is as follows:—"Take the bearing of "the light, reverse the bearing, and lay off 10 points to the right for the green light, or "to the left for a red light, then observe how many of the points so laid off are shut off by "the wind. The remainder are the points within which the observed ship is steering. "Then act as the rule of the road applicable to the case requires."

12.—This is the rule. In practice, no one who reflects on the circumstances under which the rule offers itself for application, will be disposed to doubt that in very many instances a very inaccurate approximation to—often a mere guess at—the result is substituted for a strict observance of the rule. It has to be applied on the instant, sometimes with a mind disturbed by the apprehension of danger, in darkness, in bad weather, and under unavoidable drowsiness. I admit that practised seamen may make a very accurate guess. But I submit that, if the calculation be performed for him mechanically, even an able seaman will be the gainer, and he will have his attention more free to devote himself to the execution of his duty under the rule of the road, when he can inform himself by a motion of his hand, instead of by a calculation in his head, what the exact circumstances are.

13.—It will be observed that when the red and green spot on the indicator is brought on to the bearing of the light observed, the operation required by the rule is automatically performed, and it only remains for the mariner to allow for wind.

The Pocket Indicator.

14.—Instead of affixing the indicator to the binnacle, a pocket indicator may be made thus:—

Cut out of cardboad or thin wood, a circular disc, and paint it as directed in paragraph 4 (*see* also Figs. 2, 3 and 4). Cut a segment of a circle equal to 10 points of

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the compass, and mark it as a "wind screen." Cut a disc 2 inches in diameter, and divide it as a compass card. Cut a small plan of the deck of a ship 1 inch long.

Fasten the four pieces by a screw through their common centre so that each may move freely. In the "Pocket Indicator," and the two examples given, a "wind screen" is shown.

It is, however, not proposed to adopt this "wind screen" in the "Binnacle Indicator," because the direction of the wind at sea is always present to the mariner's mind. It is given in the "Pocket Indicator" because it simplifies the use thereof.

To Use the Pocket Indicator.

15.—(1) Turn the slip on the compass card till it coincides with the course of your own vessel. (2) Set the arrow on the "wind screen" to the direction of the wind. (3) Set the lubber point of the indicator on the compass bearing of the observed light. (4) Read off the direction of observed ship's head, and note tack she is on.

Examples.

Fig. 3.—Ship's head E.S.E. Wind S. by E. Green light observed E.N.E. Ship observed is steering between S.W. and W.S.W., and is close hauled on port tack.

Fig. 4.—Ship's head N.E. Wind N.W. by N. Red light observed E. by N. Observed ship is steering W. by S., and she is closed hauled on starboard tack.

DISCUSSION.

Viscount Bury having further explained the nature of the apparatus, said: I shall show you how it is that, this indicator being brought on the bearing of the light, the operation required in order to ascertain the rule of the road applicable to the case is automatically performed. Suppose in this instance a vessel is going with her head E.N.E., and suppose the wind is S.S.E., or S.E. by S. will do just as well, and that a green light is seen two points on her port bow. There is, you observe, a collar going round the binnacle compass, and all that the man on the look-out has to do is to bring that point with a turn of his hand on the bearing of the light, and he will then see that the vessel must be going between the course S. by E. and N.E. He will see five points here, and five points in the other direction, and that she is crossing his bows to starboard, and he being the weathermost

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ship must give way. He at once ascertains the rule of the road applicable to his case. Then to take another case: suppose his head is E.S.E., and that he sees a red light S.E., and that she is going with a free wind, that red light is down there [*describing*]. Those are almost the same circumstances reversed. You see at a glance the bearing of the vessel. You merely have to turn the indicator on to the bearing of the light, and you see the vessel is going between N.N.W. and N.E. by N. The wind being here five points, that vessel's head is between the N. and the N.E., therefore she is crossing your bow, and you are going free on the port tack, and that vessel is also on the port tack; but you are the weathermost vessel, and have to give way. Take one other instance: suppose the vessel is going free here, and that you see a green light North. You take the bearing of that light, and you find that the wind being here she is a running ship, but you are on the port tack, and therefore you have to give way. I might multiply instances; but I do not wish to detain you. I merely mean to point out that, under any circumstances, by merely turning your indicator on to the bearing of the light observed and by observing the direction of the wind, you can ascertain the direction in which the vessel is going. I have some hopes that that may be servicable for saving life, and for averting some portion of the risks of collision; and, therefore, I thought I might be forgiven for bringing it before this Assembly.

Captain WITHERS: Mr. Chairman and Gentlemen, perhaps I may be permitted to ask his Lordship a question. Will you kindly place the centre vessel's head North. Please put the North uppermost. We will suppose the wind to be at West. Perhaps you will kindly put the green light bearing N.N.W. I think you said that was the weather vessel, did you not?

Viscount BURY; No, that is the running ship.

Captain WITHERS: Then in that case which vessel would have to give way?

Viscount BURY: This one, which is running free on the port tack, would give way.

Captain WITHERS: Kindly put this vessel's head North. Now I think you told us the number of points that vessel would be steering?

Viscount BURY: I could not tell you that, it is the running ship.

Captain WITHERS: Did not you say the vessel was bearing N.N.W.?

Viscount BURY: No.

Captain WITHERS: I think she would be going between S.S.E. and N.E., would she not?

Viscount BURY: Yes.

Captain WITHERS: Will you suppose that she is going S.S.E.? In that case, I think, I will call that vessel in the distance B, if you will allow me. I think she is going S.S.E. I think your Lordship is right when you say that she will have to give way; but we will suppose she is steering N.E., and I think, in that case, she would have the wind on her port side. Will you kindly tell us which vessel, in that case, would have to give way?

Viscount BURY: She would have to give way.

Captain WITHERS: How can you reconcile that with——

Viscount BURY: I am to have a catch question now, I know.

Captain WITHERS: How is the mariner to know whose duty it is to give way when, under trying and difficult circumstances, he observes in the distance a green light two points on his port bow? I think

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your Lordship led us to suppose that it was simply A's place to give way, and that there was nothing more to do. I beg to state that there are two answers to that question, and I am at a loss to conceive whose duty it is to give way. If you will make that matter clear, you will answer a question we have been trying for years to solve, but have not yet succeeded.

Viscount BURY: I think you asked me that question when you examined me once before.

Captain WITHERS: I beg pardon, I was afraid to go so far into the question as that. I was afraid of over-reaching myself, and asking you a question that I could not answer myself. Again, will you permit me to say that that vessel is steering due East with the wind at West. In that case, whose duty is it to give way?

Viscount BURY: This vessel would give way [*pointing on the indicator*].

Captain WITHERS: I beg pardon. She would be the running ship, and a vessel running has to give way. She is not on a wind. She is two points free; but a vessel to windward has to give way to a vessel to leeward. Surely your Lordship has forgotten the rule of the road since I had the honour of seeing you last. I admire your invention, and I think the British public are much indebted to your Lordship for bringing to light a subject that no man can understand. I could go on; but I am afraid I am treading on dangerous ground. Directly you pass between four points on the starboard bow round the head or other bow, whichever way you put the green or red light, there are difficulties to contend with; and I am ashamed to say that this state of things has existed up to the present time. It is the wish of many that it should be altered. It has been my fervent prayer for years that it should be altered, and how we escape in the manner we do, without serious collision, is often a wonder to me. I could go on almost to any extent, and engage your attention till I wearied you, and therefore I will, if you please, drop the subject. I certainly consider that Viscount Bury has failed to answer satisfactorily the question which I put to him.

Mr. J. SCOTT RUSSELL, F.R.S.: I am the other boy, and I will answer it. My Lord, I think we are much obliged to you for bringing this mechanical method of solving what is a great difficulty. The present rule of the road at sea is a rule which we all ought to be ashamed of; and I can only say the sooner it is put right the better. Nothing could show better the condition, and the lamentable condition, of our laws with regard to this subject, than the cross-examination to which we have just listened. I submit, as my cross-examination, that I should be allowed to state my way out of the difficulty. Now, my way out of the difficulty is making an additional rule of the road. There are too many at present. The clauses that you have to bear in mind when you see a green light in the wrong place are, I think, 160, more or less, and you have to think immediately which of all those clauses you are to be ruled by before you settle whether you will avoid a collision or not. Now, my Lord, I am going to get rid of all these difficulties, and get out of the corner into which you are put, by an additional rule of the road, and it is this:—"N.B. 161st Rule. When you have made up your mind that obedience to those Rules will "endanger your ships, break them all."

Mr. C. W. MERRIFIELD, F.R.S.: Before the Discussion goes further, I may state that the following Paper, announced to be read by Mr. Thomas Gray, "On the Rule of the Road for Sailing Ships," has, unfortunately, been mislaid this morning, and we are under the necessity of taking it as read. What it does, is to raise a question whether the rule of the road for two steamers meeting or crossing could not be applied also to the case of two sailing ships.

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Mr. LIGGINS: I should like to make a remark or two on the subject of Lord Bury's Paper. I think the question is so very easily answered with regard to that ship represented in the middle of the compass card, that I am surprised that there should have been the slightest hesitation on the part of his Lordship in dealing with it; and I think it can only have arisen from his Lordship being under the impression that it was a catch question. As I understand that card, the vessel is supposed to be steering to the North, and the wind West; and that the other vessel must be running, if the light would be seen in a position to cause danger to that ship, and by the rule of the road her position and her movements would be clearly indicated very speedily if she were a running vessel; and if she is a running vessel, she knows the rule of the road at sea is that a running vessel must always give way to a vessel on the wind; and, although I have heard much discussion, and seen a good many arguments in the papers, for months past, about an alteration in the rule of the road at sea, I can only say that, in my humble judgment, it arises in the minds of persons who are not in the habit of going to sea. I have myself been more or less at sea now for upwards of forty years, and I have never seen a collision at sea arising from the mistake of a light. It is a very rare occurrence indeed. I suppose there is not a highway in the world more completely filled with shipping than the English Coast of the English Channel; and it is a very rare thing, indeed, for vessels to come into collision, because every ship knows which way the wind is. I am saying nothing of steam boats, because they are indicated by a stem light; but with sailing vessels everybody knows which way the wind is; and unless you only see the light at the moment when you are down upon it, the collision never takes place. Each ship knows perfectly well which way the other is standing, and is able to avoid a collision; but I think this aid of Lord Bury's round the outside of the compass card on the binnacle would enable you to ascertain more correctly which way the vessel is steering. I wish I could understand that apparatus more clearly than I think I do, because anything that would improve the system and refresh the mind as to the exact course a ship is steering would be a step in the right direction. I, for one, have never seen any necessity for any alteration of the present rules. I think they are very simple—very few to retain on the mind; and no doubt the Paper of Mr. Gray will be very useful to many minds who are not quite so quick at perceiving that which it is their duty to do.

Captain SCOTT, R.N.: This Discussion puts me in mind of a catch question that used formerly to be put to midshipmen when they were passing a competitive examination for a lieutenancy. The question put was this:—"If you were upon a lee shore, and your ship would neither tack nor wear, what would "you do with her?" And when the midshipmen could not tell him, the captain said, "Let her go "ashore."

Mr. MACFARLANE GRAY: About three years ago I made a complete apparatus like this, bringing in every contingency of wind, and telling the man steering what he was to do. I decline to show that to-day because it has been proposed now to alter the rule of the road at sea; and as my apparatus only tells a man what he is to do according to the present rule, if that rule is altered, a variation in the apparatus may be required.

Captain SCOTT, R.N.: I venture to say that the mechanical means which have been brought forward by Lord Bury are very valuable indeed. As one who has commanded a vessel in the Channel, and who has been knocking about in squadrons, I know how difficult it is to escape from running over other vessels. I am sure the mechanical means which Lord Bury has now brought forward, although they are not so perfect as they might be, may be made still more perfect, and they certainly convey to my mind

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a very clear notion of the state of things which I should in my past experience have been glad to have had the benefit of.

Captain WITHERS: I think that the same rule which now exists with regard to steamers should also be extended to sailing ships, *viz.*, that the vessel which has the other on the starboard side should be the vessel to give way. When two vessels are meeting so as to involve meeting end on, then they should both port. Such, I think, is the contemplated rule of Mr. Gray, and as I said before, the vessel that has one on her own starboard side should give way.

Mr. MACFARLANE GRAY: I think I have proved beyond doubt that this is a question to which two answers can be given. It seems to me that it is unnecessary to go into the question of the old rule; but I have simply endeavoured to prove that the contemplated rule will be infinitely superior to the old one in many respects, if not in all. I think that when two vessels are meeting end on, they should both port. The next question will be as to two vessels on a wind. We will suppose the wind at North [*illustrating it by the model*]. Mr. Gray's Paper raises the question whether the rule of the road for two steamers meeting or crossing could not be applied also to the case of two sailing ships meeting or crossing. A steamer will always have to get out of the way of a sailing ship, as at present.

Mr. J. SCOTT RUSSELL: I think this is a simple mechanical method for solving a complicated set of questions which arise on the existing rules of the road, and is therefore of great value.

Viscount BURY: I thought the Society of Naval Architects would like to have laid before it any simple contrivance with the object of preventing collision, and for that reason I ventured to bring this matter before you.

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ON THE RIGGING OF SHIPS.*

By W. F. Fleming, Esq., Associate.

[Read at the Sixteenth Session of the Institution of Naval Architects, 19th March, 1875; Joseph Woolley, Esq., LL.D., F.R.A.S., Vice-President, in the Chair.]

The dismasting of well-appointed vessels has lately become of frequent occurrence; various causes have been assigned; amongst others—

1.—Carrying on a press of canvas. Captain anxious to make a *passage.*

2.—To being fitted with *iron* masts and wire rigging: no "give" in anything.

3.—To the heavy cargoes carried, occasioning unusual labouring of vessel and consequent strain upon masts, &c.

As to the first reason, very few vessels have their masts taken out of them, *solely* from the pressure of their *canvas.* A few light spars may give; but I have invariably noticed from personal observation, if too much sail is *persistently* carried, it generally performs the operation of taking itself in, before dismasting the ship.

Secondly, as to iron masts. There can be no question as to their superiority over wooden ones; however, unless carefully constructed and of the best iron or steel, many instances will arise of their utility being questioned; but this may occur in the building of the *hull itself.* Defective iron plates as regards the quality of the material, will be sure, sooner or later, to expose a weakness. It is self-evident that the greatest precaution must be exercised in procuring sound material—a material so extensively employed in shipbuilding, and so much structural strength depending upon its *quality.*

Thirdly, as to heavy cargoes. This opens too wide a subject for me to deal with here—height of freeboard and proper stowage, and other vexed questions. I shall now confine myself to what I consider one of the chief causes of vessels losing their masts

* Received 8th December, 1874.

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(of course excluding accidents, in hurricanes and similar weather). It is to the present defective plan of rigging vessels, especially in reference to the position of the *stays.*

Each mast should sustain its own individual strain, whether arising from the pressure of the sails, pitching, or rolling motion of the vessel; and, therefore, the *stays* should be fitted independently, and have no connection with other masts.

According to the present plan of rigging a ship, all three masts are more or less bound together. Their collective strains invariably, when the ship is plunging and making bad weather of it, concentrate on the forestay and bowsprit, and when once those give, the chances are ten to one that the foremast goes by the board, dragging with it main and mizen, topmast, top-gallant masts, &c., &c. The accompanying sketches will explain the manner I propose leading the principal stays, so as to act independently.

Tops and cross-trees are gradually assuming very small dimensions, which, though neat in appearance, strike me as a sacrifice to utility. A good spread to the topmast rigging is most desirable; and, as topsail yards are now fitted, they can be braced up as sharp as is required, without being disadvantageously jammed against the rigging.

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ON A NEW RIG FOR SHIPS.*

By R. B. Forbes, Esq., of Milton, Mass., U.S.

[Read at the Sixteenth Session of the Institution of Naval Architects, 19th March, 1875; Joseph Woolley, Esq., LL.D., F.R.A.S., Vice-President, in the Chair.]

The new rig for ships which I propose embodies so many new and untried devices, that nothing short of a miracle would induce any one *on a cursory examination* to take such a long step as to bend his sails by the foot, and sling his lower yards above the trussle-trees to the masthead, and to find his masts carrying the top-gallant sails, or upper top-sails abaft. If it required ten years to introduce the double topsail—which is a fact—how long will it require to introduce the new rig? If, however, any competent seaman will examine well the new ship rig with an unprejudiced eye, he will see the following important features in it. The sails being bent by their longest side, the foot—roped all round with one size of rope—will set better, cost less, and be more durable. They can be triced up, guided by leaders or jack stays, by the tricing tackles, much easier than the old sails can be sheeted home and twisted with the heavy yard attached. The sails can be handled in rough weather by fewer and less competent men.

When the sails are furled the yards can be braced much sharper, and with much less strain on yards, rigging, and braces, than in the old rig. The courses may come to the deck to be furled or hauled up as usual, or bent to the yard for sea-use in long runs; but when it becomes necessary to stow them, they must come to the deck just as the square sail of a large schooner comes, except that it is guided to the deck by jack stays or guiding gear attached to a short spar on the foot, which, being held by a stout tackle to the deck, assists much in controlling the sail, and renders heavy tacks and sheets unnecessary. The topsails may be reefed much more easily than a close reef can be taken in the old sail, because the men have more room to operate in hauling out the earrings, and a slack sail to handle instead of one full of wind, braced in so as to frequently endanger the men. The topsails coming down squarely, parallel to the lower

* Received 5th December, 1874.

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yard, guided by jack stays, and assisted by downhauls, and by connections between the belly of the sail and the jack stays, can be furled by four unskilled men.

It is not too much to say, that two or three men, by rolling up the sail under them, little by little, fleeting along, can furl—and furl well—a topsail of large size, when ten or fifteen men could not furl the usual reefed topsail in a gale, when clewed up. As the top-gallant sails, or upper topsails, as they are often called, have no reefs, and are of lighter canvas, they come down by a slightly different process to the topsail yard; that is to say, the two outer corners, known to experts as the head cringles, double down, guided by jack stay and assisted by downhauls, to a point on the yard equal to the length of the deck, and if the sail be of the right proportions this will bring the head from the centre support down at the same time, thus reducing the sail fully one-third. To furl it, only the centre supporting tackle, or tackles, to be lowered and the slack lines hauled in; the sail can then be furled by four men, and its yard, with the royal yard and the foremast, can be easily sent down, leaving the canvas and topsails to be set without hindrance.

In order to compare the rig with the present double topsail, I will suppose an unlikely case—a heavy squall. If you let fly every tricing tackle, including those of the courses, nothing very serious happens, and the downhauls may be manned by marines and steerage passengers, and the sails got down, for better or worse, without damage. Suppose in a similar case in the old rig you let fly sheets, tacks, and halyards, your yards are not kept in place, and all the skilled men you can hope to muster cannot save your sails, and you may lose yards and masts. I do not mean to say that my new sails coming down by the run are going to stay perfectly quiet in a heavy squall, but I do believe they would be safe as compared to the present rig.

Fig. 1 (Plate VIII.) shows a ship rigged on my proposed system, in which the stay-sails A, B, C, and D come down to *a*, *b*, *c*, and *d* respectively; the royal E furls as usual, the top-gallant sail or upper topsail F furls on the topsail yard, and the topsail G furls on the lower yard. Fig. 2 shows the upper topsail partly hauled down. It is furled by lowering away on the centre tricing tackle. As may be seen, it has no head-spar like the topsail or course; but its yard may be lowered, if required, as the stay goes above it as usual. Fig. 3 represents the topsail partially hauled down, which is done by letting go the two outer tricing lines and keeping the two head-spar tackles fast, when the leech comes taut along the yard. To take it in, the tricing tackles A A are lowered, and the head-spar is brought down. Fig. 4 shows the course set. By letting go A, B, C, D, and hauling down the head cringles, the sail assumes the shape indicated by the dotted lines, the cringles travelling down on the jack stays E and F. The jack stays

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H and I being then lowered, the sail comes down on deck. The sail, however, can be bent to the yard at sea, and worked as usual, in which case the foot-spar K takes part of the strain, and heavy tackles and sheets may thus be dispensed with.

It will thus be seen, that the courses may be taken in piece by piece more readily by far than in the rig now in vogue. At present we have only one course to pursue in a merchant ship:—call all hands, man the weather clew garnett and buntlines and leech lines; haul up the weather clew, then start the sheet, when amidst much slatting and labour you get the sail hauled up; then all hands are required to furl or to reef it.

In the new rig, the principal strain being on the foot-spar tackle, much less labour is required to *clew down* the head cringle; the head spar is then lowered away until the sail is brought down under the lee of bulwarks, or to the deck in a ship or steamer with a hurricane deck. When on deck, soldiers or marines, or steerage passengers, can reef or furl it ready to go aloft with less work than competent seamen could handle the same sail bent as usual by its head. Every seaman knows that the mainsail in a merchant vessel in a strong breeze, while the most useful propeller, gives more anxiety than any other sail; it is often taken in and kept in much more than it ought to be on account of the difficulty of handling it in squally weather. The question is frequently asked as to the number of running ropes required to reduce my sails.

Let us examine into this. The ordinary topsail requires two heavy sheets, tie, runner and halyards, which I call three purchases, two clew lines, two buntlines, two spilling lines and the braces (*two at least*) to tend, making—to say nothing of bunt and clew jiggers—eleven ropes to handle. In the new rig we have six tricing tackles to let go, not requiring any tending like sheets, ties and braces, and six downhauls to haul upon; thus simplifying the operation of furling or reefing very much.

My new top-gallant sail, or upper topsail, being the sail to be handled very much more frequently than the lower topsail, is the one requiring means to reduce it easily, and as it is much smaller than the upper topsail of the *Howe's* rig, it requires less work to reduce or to furl it, particularly as it comes down lower to furl.

In the *Howe's* rig, which is a modification of my original double topsail, as applied to the *Massachusetts* and *Edith*, the lower topsail yard is hung to the cap or near to it, and the sail is of the size of a close reef sail; this dispenses with ties and halyards, and saves much reefing, but it leaves the two sails above it, which are to be handled more frequently, of larger area, and the lower sail never sets very well, has a large gap under its foot, and is greatly strained by reason of the lower yard and the topsail yard moving

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on varying arcs of a circle, the one standing out at arm's length from the mast, while the other turns on a much smaller arc, close to the masthead.

In a steamer, especially a war steamer, in war time, great advantages will be found in being able to house the pole mast and send down the upper yards, the largest without its sail, or to leave the latter aloft and brace it fore-and-aft without cramping the rigging. It will very seldom be expedient to send down the upper topsail yard at sea or in port, unless quite sure of a hurricane; but it is very often expedient, going head to wind, to save coal by reducing top hamper.

Men-of-war naval experts, are generally so strongly wedded to old customs, that it will be difficult to reconcile them to any new system. Not long ago they condemned the idea of patent trusses, iron gun carriages, iron screw lanyards to rigging, and many other things recently introduced in merchant ships and in men-of-war. The custom of piling up strand after strand on the masthead, and then riding down the pile by putting the stay over it, is one of the most clumsy and damaging contrivances, and only goes slowly out of fashion, by reason of the introduction of iron masts, cross-trees, caps, and rigging. It is mortifying to see how completely the blacksmith and the iron worker has taken precedence of the marlingspike sailor in the rigging of ships, and how completely the machinist and engineer has gone before him in propelling and working them.

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ON THE RELATIONS EXISTING BETWEEN SHIPBUILDERS, SHIPOWNERS, AND SHIP INSURERS.*

By W. M. Fenning, Esq., Associate.

[Read at the Sixteenth Session of the Institution of Naval Architects, 19th March, 1875; the Right Hon. Lord Hampton, G.C.B., D.C.L., President, in the Chair.

The relations existing between shipbuilders, shipowners, and underwriters, and the effect these relations may have upon the safety of navigation, is a subject well deserving the consideration of this Institution; and a discussion on it can hardly fail to throw considerable light upon one of the most difficult and important questions that has ever occupied the attention of the country.

It appears now to be generally admitted by those who have studied the subject, that a considerable amount of the loss of life and property at sea, which has of late years attracted so much attention, is traceable, more or less directly, to insurance—or in other words, it is felt that if there were no insurance there would be fewer losses.

This undoubtedly is the fact. Marine insurance, as at present carried on, is indirectly a source of danger to the lives and property of the public; whilst marine insurance, as it could and should be carried on, would, I believe, prove to be the most efficient safeguard that the public could possess; and for this reason, it would place between the endangered interests—the lives and property of the public, and the element of danger, the excessive competition of the present day—one of the most potent barriers it is possible to conceive, *viz.*, the self-interest of a united and powerful community.

How is it, then, that this influence, which should be a safeguard, has in effect become a source of danger? The reply is not a difficult one. The underwriters are not a united community, and therefore they are powerless. Their want of union, and utter absence of organisation, render them an easy prey to those who take advantage of these circumstances; and it is impossible not to feel that so long as they continue in their

* Received 19th March, 1875.

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present disorganised condition, unable to protect their own interests, it would be folly for the public to expect them to protect theirs.

To impose therefore some check upon the reckless building, loading, manning, and navigation of our mercantile marine—evils directly arising from an ever-increasing competition—many people are disposed at once to invoke Governmental interference, and to trust to that as the remedy—and at first sight this would appear to be the easiest way out of the difficulty—while a more intimate knowledge, and a careful consideration of all the circumstances connected with this most complicated question, lead others to say, "Let us have Government interference only as a last resource, and if it can be shown that no other means are available."

The matter, however, is urgent. Too much valuable time has been lost already in fruitless efforts to remedy these evils, on the one hand by direct legislative enactments, on the other by bringing into play the latent powers of the underwriters. We all admit that something should be done. Let us therefore examine what chance we have of coping with the difficulty in this latter direction, and in order to facilitate this examination I must ask you to trace with me for a few moments the steps of insurance from its earliest infancy; I will then proceed to show you its present condition, and leave you to form your own judgment as to whether we are justified in relying upon the power of the underwriters to remedy the evils we all so deeply deplore.

There has been much discussion as to where and when insurance was first practised, but there can be no doubt that it and commerce have grown up together, each necessary to and supported by the other; that, as commerce expanded, the necessity was realized of distributing among various persons the risks of loss which would be disastrous to an individual. Some writers trace it back to the times of the Romans, while others assert that the idea was borrowed by the Florentines from the Jews, and that it was carried on in Italy as early as A.D. 1194. Existing documents show that it was practised by the Venetians as far back as 1411, and although the date of its introduction into England is uncertain, it is evident it was in use here in 1512, as in a Venetian State document of that date attention is called to the fact that English underwriters were insuring Venetian property.

For a considerable period the insurance business in this country appears to have been carried on by individual merchants, who met in certain coffee houses in the neighbourhood of Lombard-street for that purpose; and the fact that the proprietor of the favourite coffee house, opened in 1710, was named Lloyd, and that his establishment became the principal resort of the merchants and underwriters of the day, gave rise to the name of Lloyd's—so well known, and so little understood, all over the world. I need

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not occupy your time by detailing the circumstances of the formation of the various insurance companies. It is sufficient to say that the two oldest companies, the Royal Exchange Assurance and the London Assurance, were formed in 1720, under a charter and with exclusive privileges; and that for the next ninety years they and the assembly of private underwriters—"Lloyd's"—had a monopoly of the insurance business of the country. It became evident, however, that the existing facilities for insurance were not sufficient for the vastly increased business of the country, and in 1810 a motion was brought before Parliament "to consider our present means of effecting marine insurance," and it was shown that greater facilities were offered abroad than here; for instance, that in Hamburg alone there were no less than thirty-six marine insurance companies.

The result was that the exclusive privileges of the two old companies were repealed, but nothing appears to have come from this till 1824, when two more companies started, followed in 1836 by five others. There are now some twenty marine insurance companies in London, besides companies and associations in all the chief mercantile cities of this country and abroad, all in active competition against one another, but without any organisation for combining or securing united action in those numerous cases where this is essential to their interests.*

As the business increased the necessity for some record of the vessels they were called on to insure became manifest to the underwriters, and to meet this an Underwriters' Register of Shipping was commenced in 1760. In 1798 the Shipowners started a Register Book of their own, and in 1834 these two combined to form the present Lloyd's Register Book.

For their subsequent history I cannot do better than transcribe bodily a portion of the answer to Question 8,203, from the Evidence before the Royal Commission. "In 1841 "there was an opposition book started at Liverpool. The competition caused by that book "worked very badly, and tended to ships being sent out in an inefficient state. That "went on until 1845, when an amalgamation took place between Lloyd's Registry and "the Liverpool Book, upon which the Lloyd's Registry gave to Liverpool a branch of "the London Committee. That went on till 1862, when there sprang up the Liverpool "Iron Registry. The gentlemen connected with that Society go in for business, and they "know very well that, unless they can induce builders to think by going to them they "will be able to get a much lighter ship and a cheaper ship classed than by coming to "us, they will not do any business; and the consequence is that slim ships have been "built, till at last ships are produced which are not satisfactory, and such ships as ought "not to be allowed to go to sea. That is the result of competition. Competition may

* See *Manual of Marine Insurance*, by Mr. MANLY HOPKINS.

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"be good in some cases, but certainly it is not good in the classification of ships, "therefore I would stop all competition; and I think that the Government ought to "step in and say, 'We will have a classification but it shall be by one properly "constituted authority.'"

The *Veritas* was started in 1828, and there are now some twenty-one different register books, many of them, however, employed apparently only for the purpose of registering the vessels of their respective nationalities, but some of them in competition with each other and the three first-named books. For the present, however, we will only consider the part these three principal registers bear in relation to the question before us.

It is very important to bear in mind that these three register books all depend for their income upon the fees they receive for registering ships, and the sale of the books themselves. They have, therefore, a clear inducement to register as many vessels as possible, and have been in active competition together with that object in view.

Now we all know that the lighter you can make a vessel of any given size, the greater will be the quantity of cargo that she can carry, and the less will be the cost for materials in her construction.

The vessel so turned out may probably strain herself and damage her cargoes, but as in both these cases you can generally saddle the underwriters with the resultant loss, neither the owner of the vessel nor the merchant who entrusts him with his goods are very great sufferers.

If the loss and damage occasioned by these inferior vessels fell directly on the owner and the merchant, there would be a speedy stop put to the building of them; but as the responsibility is shifted on to the shoulders of the underwriters, it is not surprising that in these days of competition so many vessels are built with a greater regard to cheapness than to strength.

The result of this is that there has been a demand for cheap vessels, but to get them insured it is generally necessary to have them classed, and to get them classed the competition existing between the register books has been taken advantage of; so that as one Committee reduced its requirements, the other followed suit—not, be it observed, because it considered the other one right, but simply to prevent it taking away its business.

I leave to practical and scientific men the discussion as to what amount of iron is necessary in any given structure, and merely point out the fact that the reduction of that amount by the register books has been due more to pecuniary than scientific reasons,

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and that so long as they are subject to such considerations their influence must be detrimental to scientific shipbuilding, and to the safety of the sea-going public.

So much for the quantity of the iron. Let me now add a few words as to its quality. The same competition and demand for cheapness has been allowed to prevail in this respect also, and rather than risk the diminution of their business, the register books have knowingly permitted the vessels they have surveyed to be built of iron they have considered unfit for the purpose. In support of this let me again quote *verbatim* from the Evidence before the Royal Commission.

"10,964. Would you propose that iron plates should be tested in the same way that "anchors and chain cables are tested?—If they were tested it would have a good moral "effect. Very bad iron is put into some ships. Those who require better iron pay a "better price. While there is this competition you cannot have the material that ought "to be produced for building ships.

"10,965. Why do not you put a stop to the use of that inferior iron now? That "iron, as I understand you, is being put into vessels which are classed in your books.— "If we were to say at once, 'We require the iron to be subjected to this or that test; "'that it must bend to a certain angle cold, or must stand certain conditions warm; or "'it must go through such and such tests,' what would an iron manufacturer say? He "would say, 'If you want iron of this extra quality we must have £2 or £3 a ton "'more;' and he would go off to some other quarter, and supply shipbuilders with the "inferior iron, where there were not those restrictions.

"10,966. You mean that there is competition between Lloyd's and the Liverpool "Registry and Bureau Veritas?—Yes.

"10,967. You prefer retaining your connection to making an effort to insure the "putting of good material into ships? Without wishing to put it offensively at all, you "mean this—if you were to say to shipbuilders and shipowners, 'We must have good "'iron (I do not mean to stand the Admiralty test, but a fair and reasonable test),' the "shipbuilders and shipowners would immediately say, 'We will go to the Liverpool "'Registry, where they do not ask such a thing,' and the consequence would be that "you would lose your business?—Yes, many would leave us for considerations of "that kind.

"10,968. Therefore you prefer keeping your business to having good iron?—Yes, "within certain limits, of course. We do not impose tests, but we do the best we can "in a more indirect way.

"10,969. Are there a good many ships classed at Lloyd's which are made of bad

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"iron?—Yes, and classed elsewhere also; of iron which would not have been used for "shipbuilding a few years ago."

After evidence such as this, I think no one will deny that, notwithstanding their great value in many respects, these register books, as at present constituted, are thoroughly untrustworthy as guides for future shipbuilding; and that, if the competition that exists between them induces or has induced them to subordinate the consideration of the safety of human life and valuable property to the determination to maintain their incomes, it is clear that such competition must be put a stop to as speedily as possible.

To do this will doubtless be a difficult, but by no means an impossible, task; and I would suggest, as one solution of the difficulty, that these three principal Societies should amalgamate and work under one central Committee, and that the Institution of Naval Architects should be represented on this Committee by some of its most scientific and best-known Members. That this amalgamated Committee—better able than any Government surveyor to determine such vexed questions as load lines, &c.—should meet from time to time, and, unbiassed by pecuniary considerations, discuss the many important questions constantly arising in this progressive and inventive age. If some such method as this were adopted, I believe the science of shipbuilding would be benefitted, and the lives of the seafaring public rendered more secure.

I may mention, incidentally, before leaving this part of my subject, that a few days since I paid a visit to the establishment of Mr. David Kirkaldy, the well-known tester of iron and other materials. I asked him if he often tested iron used in shipbuilding; he replied, that in his experience of nine and a quarter years he had, with one exception, only tested the iron of four ships, and they were for a foreigner. The exception was in the case of one gentleman, who is at the present time having several vessels built of iron warranted to stand a certain test, and who, in the course of construction of these vessels, has more than once had occasion to reject the iron that was being put into them. On signing the visitors' book, I was glad to see that the four previous visitors had been gentlemen connected with the Lloyd's Register Book, and I hoped that this was an omen pregnant with good for the future.

Having traced the effect of competition upon the building and registration of vessels, I will now revert to our mode of insuring them, and will show you that the same influence has had an equally baneful effect in this direction also, and to do this I will trace an insurance through its various stages.

In the first place, we have the merchant or shipowner, who has property to insure. Occasionally, but very rarely, he goes direct to the underwriters; but usually he employs an insurance broker.

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The broker's business is to effect the insurance at the lowest possible premium, and if he fails to do this, his principals will soon hear of it, and he will probably lose his business. In the event of damage or a loss occurring, the broker has to recover this from the underwriter, and he has to take care that no other broker gets a more liberal settlement than he does, or that also may imperil his business. I need hardly add that there is a vast amount of competition among the brokers. If it is a total loss, he applies direct to the underwriter; but if an average or partial loss, he places the matter in the hands of an average stater.

An average stater has no official position, but is an irresponsible agent who has made it his business to make up claims upon the underwriters. As he is chosen and employed by the person making the claim, and as there is also a keen competition among the average staters, he is too often induced to insert in his statements amounts for which the underwriters are not liable, knowing that he may lose his business by a too conscientious want of compliance with the wishes of his principal.

The vessel or goods on which the claim arises is often insured in various places, and as there is an utter absence of organisation among the underwriters, they frequently settle claims and losses in entire ignorance of what their fellow underwriters on identical interests are doing.

The result of these relations between the shipowner, the broker, the average stater, and the underwriter, is that the underwriter is constantly burning his candle at both ends. Competition is forcing him to reduce his premiums to an unremunerative point, and to settle claims and losses for which he was never liable.

I will not, however, dwell on the reduction of premiums, for that is the underwriter's own affair, and does not affect the question before us; but the reckless settlement of claims is quite another matter, and is at the root of all this evil. As an instance I may quote the following case, in which one firm of average staters made up a claim on the underwriters for particular average on a steamer, amounting to £10,950, or £25 9*s.* 5*d.* per cent. on the policies, while another firm to whom the case was referred made it amount to £1,334, or £3 2*s.* 1*d.* per cent. The underwriters eventually paid £22 8*s.* 5*d.* per cent., or £9,852, and at a final meeting of those interested in the case, some who had previously settled stated that had they known that other underwriters were willing to act with them they would gladly have contested the case, as they considered it a gross imposition, and a resolution was adopted urging the Committee of Lloyd's to adopt some measures for facilitating united action on the part of the underwriters.

I may mention that the larger portion of the above claim was for doubling the

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vessel's sheer strake, and adding what was practically an iron deck; in fact, for rectifying original defects in her construction.

The effect of this recklessness in the underwriter's settlements is two-fold: it empties his own pockets, for which result he has only himself to thank; and it indirectly encourages unseaworthiness in the vessel he insures, and this is a matter for the public. The remedy does not lie, as many may seem to suppose, merely in a general increase of the premiums; for that is only making the good shipowner pay for the bad, without touching the root of the evil. The real remedy, I believe, is to be found in the underwriters combining together to resist all losses arising from unseaworthiness or fraud. The want of this combination is daily more and more felt, and the desirability of it is admitted by all underwriters who devote honest thought to the subject. The abuses to be dealt with, however, are deep-rooted and of old standing, and there is a wonderful amount of prejudice and indifference to be overcome, to say nothing of the opposition of hostile interests, before any such great measure of reform as is needed can be carried out.

The state of the law also on various points connected with insurance is very unsatisfactory, and is answerable for much of the recklessness displayed by the underwriters, who frequently submit to barefaced swindling rather than seek such justice as the present state of the law affords.

The legal decisions with regard to unseaworthiness are simply childish. By a legal fiction, the absurdity of which I will endeavour to show, an underwriter on a policy for time is precluded from raising the plea of unseaworthiness. For instance, if a new vessel starts on her first voyage, say from Liverpool to Madras, and founders either from overloading or bad workmanship, or both, before she has been twelve hours at sea, the underwriter, if on a policy for the voyage, can raise the plea of unseaworthiness, but if on a policy for time for twelve, six, or even three months, he cannot do so; or again, if the same underwriter has half his lien on the vessel for the voyage, and the other half on the same vessel for time, he can contest the seaworthiness of the vessel as to the first half of his lien, but not as to the second. I must apologise for alluding to what you all must be so well aware of; I only do so as it seems to me that a little determination on the part of underwriters would soon cause this absurd decision to be reversed.

Having as briefly as possible pointed out the influence that insurance, as at present carried on, has upon shipbuilding, I must leave you to decide whether or not the underwriters themselves have, or should have, the power of successfully dealing with the whole of this question.

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It would be an insult to the science of the present day to assert that shipbuilders cannot build vessels capable of coping with the worst weather they are ever likely to encounter. But such vessels require good workmanship, good materials, good stowing, and good management, to say nothing of good design—in fact, to be thoroughly seaworthy; while competition encourages slovenly work, cheap materials, rapid and deep loading, under-manning, and a form that will earn the greatest amount of freight upon the smallest expenditure of capital.

These latter qualifications are not all conducive to seaworthiness; but if the underwriters would only combine to insist upon the seaworthiness of the vessels they underwrite, I feel confident the naval architects would not be behindhand in producing the article that is required.

DISCUSSION.

Mr. Clifford Wigram: My Lord and Gentlemen, there is one subject connected with Marine Insurance which has been overlooked by the writer of the present Paper, who has treated the question almost entirely as if it were a question of insuring ships. A great deal of insurance is also done upon the cargoes, and the recklessness—I would almost say the criminal recklessness—often displayed by underwriters in underwriting cargoes without fully understanding what ships are to carry those cargoes, in my opinion has a great deal to do with the present state of the case. Everybody in this room will understand what I mean when I allude to open policies, a system by which cargoes are insured to come in any ship by which they may be shipped hereafter. I firmly believe that that system is really at the root of a great deal of the present recklessness in the way in which ships are built, manned and loaded. If underwriters would insist upon knowing beforehand by what ships the cargoes they are asked to insure were to be shipped, they would then know what owners they were trusting; they would then trust far more to the character of the owner than to the ship itself, and we should hear much less of losses taking place at sea than we do at present. The great competition among underwriters has induced them to accept from merchants risks on cargoes to be brought from abroad by any ships which the owners of the cargoes may choose to ship them in. The consequence is that the careless shipowner has no very great inducement to keep his ship in proper order, so long as she is classed at one of the Register Societies, knowing that being a first-class ship (as it is called) she will get cargo at the current rate of the day; whereas if underwriters were fully aware of what ship the cargo was coming by, the first-class shipowner, instead of the first-class ship would get the preference, and the difference of premium on the cargo would insure to his ship a preference in the freight market, and he would be able to load his ship while others were lying idle. I think that putting an end to open policies would do more than any measure that can be brought before Parliament, to cause ships to be kept up to that state of efficiency in which they ought to be.

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Mr. LIGGINS: It has been my habit for upwards of thirty years to insure cargoes by ship or ships, but I have always understood that those ships were to be found in Lloyd's Register. For many years my ships were surveyed every year. I have had large amounts of produce shipped in various vessels, but the understanding always was that it was to come in ships in Lloyd's Register; and therefore, known to the underwriters and the insurance offices in London in which the cargo was insured. I must say that I have been so fortunate as never to have had a total loss. Sometimes I have had a claim arising for leakage in very severe weather in the winter months in crossing the Atlantic ocean; but I have never had a total loss of a ship during a period extending over forty years. I believe that what is required more than anything else is that there should be a compulsory examination of ships, and that shipowners should not be the sole judges of the seaworthiness of their own vessels. If there was a compulsory organisation of surveyors who were required to survey specially every three years, and regularly sent to look at a ship once a year or whenever that ship came into port, we should not hear of such constant losses of ships in consequence of unseaworthiness. I think that is a thing for which we have a right to look to the Legislature to interfere on behalf of the public interest. With regard to the amount of insurance on ships, it has never come within my knowledge that as a rule ships were insured for a larger amount than their value with a view to the loss of those ships. According to my experience among my friends who are shipowners, I have always found the most honourable and upright spirit. They were men whose pride it was to see their ships come into port, even in the most terrific weather, in a high state of efficiency and ready to take in a new cargo and return to their work. I believe that to be the character of shipowners as a rule; but, of course, among all classes of men, there are some few black sheep, and it may be necessary that those black sheep should be looked after by an Act of Parliament. The honest shipowner, I think, has no need to dread any legislation in that direction. I, for one, am of opinion that Mr. Plimsoll has brought before us a question which as a nation we are bound to respect. It is too true that when we take up the papers we see constantly recorded an amount of loss of life and shipping which is perfectly startling and horrible. It is a gloomy dozen lines every morning that records the loss of life and of valuable and beautiful ships which with greater care in their equipment and management would not have been lost. I had myself some interest in two ships which have been mentioned of late in the columns of the *Times*, with regard to both of which there was the most culpable neglect on the part of captains. The loss of one was owing to recklessness on the part of the captain in running a valuable mail boat on shore; and another was where a West India steam boat had the narrowest possible escape from meeting with a similar fate to that of the *Northfleet*, simply because of the parsimony of some wicked shipowner who did not carry lights on his vessel, the consequence of which was that the steamer was unable to see the approaching vessel. I think Legislation is required to make the carrying of lights on all ships compulsory. I have very often been up and down the Channel, and have so frequently seen ships without lights that it makes one almost afraid to go to sea, because you are thus left at the mercy of some reckless man who may be utterly careless and culpable in his management, and who does not obey the law by exhibiting those lights which are required for the general safety.

Mr. CHARLES LAMPORT: I think the speech to which we have just listened is the best commentary that can possibly be on inspection or compulsory registration. The last speaker has told us that it is necessary that insurers and shipowners should depend upon registration, and he has specified Lloyd's as a place where ships should be registered. Now I do not know whether that gentleman is aware—I am sure

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he must be, but he omitted to state it—that Lloyd's classification gives no indication of the strength of a ship; it is an indication of the duration of a ship, but not of its strength. If this gentleman insures his goods by a ship or ships with the understanding that they are to occupy a certain class in Lloyd's Register, it may be necessary to say whether that class should be, if they are wooden ships, A1 for four years or A1 for fourteen years; but I, as a shipbuilder, know that the difference is not in the strength of the materials, but that the classification is assigned to ships in respect of their probable duration. Now, an A1 ship for four years or for seven years, built of soft wood, is not capable of carrying cargoes so well as an A1 ship for fourteen years, and if that gentleman thinks it enough that the person insuring his goods should specify that they are to be classed A1 at Lloyd's, he is labouring under a misconception and enticing the shipowner not to aim at the best ship, but to be content with a low class. That is one reason why, I think, shipowners should depend upon themselves, and not look to any system of classification. Then with regard to what has fallen from Mr. Fenning, I have been most agreeably disappointed. Listening to Mr. Fenning, knowing that he was going to read a Paper this evening on the question of insurance, I fancied that I should have heard repeated the indictment of over insurance, that has been dinned into the ears of the public during the last two or three years of Mr. Plimsoll's agitation against shipbuilders and shipowners. Now I feel pleasure on this occasion to find that Mr. Fenning is coming forward in the most heroic manner and taking upon himself, or rather upon the underwriters, to which class he belongs, the stigma which we, the shipbuilders and shipowners, have been labouring under during the last two or three years. The statement was made in the House of Commons when Mr. Brassey introduced the question of insurance, that it was the key to the whole of this important question of preventible loss of life at sea. I am quite satisfied that it is not so; and when it is stated that with a view to using this key to prevent that loss of life, you ought to apply legislation to questions of insurance, it seems to me that the cart is put before the horse. If the Legislature is to tell Lloyd's insurers—sitting in that large ill-ventilated room which they have at the Exchange—how they are to carry on their business, what will these gentlemen become? They would not be carrying on business on their own account, but as mere servants and agents of the Board of Trade, and if the same sort of thing were to take place with regard to the compulsory classification of ships (if the Government will themselves take the responsibility I have no objection); all I can say as a shipbuilder and a shipowner is, that if I am compelled to class my ships I am absolved from all responsibility, and whatever happens to that ship, if the Government inspector has passed her, I could plead inspection in any court of justice as a justification for sending the ship to sea in the condition in which she was. Of course it would take too long to go into all the details of what would be necessary in order to make up an efficient inspection, but I sum them up and say that it must be of all or nothing. It must begin with the model of the ship; it must go on with the specification of the dimensions and the materials of the ship; it must deal with the workmanship and equipment of the ship; and it must not be satisfied with that, but when the ship is loaded there must be an inspector looking about to see that she is properly loaded, for anybody knows that with a given amount of cargo of varying density and weight the ship can be made so to labour at sea as to throw her masts over her sides or to be as easy in her motions as possible. Therefore, in loading you must have inspection, and, not satisfied with that, inspection of the work at sea. I think I told you yesterday from the Government returns that out of the whole of the losses enquired into for the last twenty-seven years, 4½ per cent. on those losses has been attributable to unseaworthy ships and 69 per cent. has been attributable to carelessness, indifference or ignorance on the part of the crew and the captain. Therefore, I say if you want

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by inspection to stop this great loss of life and property at sea, you must send an inspector to overlook the captain in a storm and to tell him when to take in this sail or that sail, and how he is to do this, that, and the other, and the captain and crew must be altogether under the hands of the inspector. Well, Gentlemen, I think that is the *reductio ad absurdum*. But, reverting to the question of insurance, I will say that it may be made the bottom of the whole question. It is not founded on individual investigation, as it ought to be; but it is founded on traditional usage. I am happy to find, from the tenor of Mr. Fenning's Paper, that he disapproves of the system carried on, and his observations are a complete condemnation of the system of insurance carried on in London. I have had some experience as an underwriter in Liverpool, for a period of fifteen years, and the result of my operations have never amounted to a loss except in one year, and that was when the well-known cyclone took place at Calcutta, which was perfectly exceptional. I have friends who are connected with underwriting in London who tell me that it is a miserable business. I do not know whether Mr. Fenning would say so. If it is a good business underwriters have no right to complain, and if it is a wretched business why do they want to go to the Legislature and bring their case before the public with a feeble wail, when they have everything in their own power. If they are dissatisfied why do they insure bad ships? Why do they depend upon Lloyd's Register when they think that Lloyd's Register deceives them? Why do they not establish their own system of inspection, as at Liverpool, where there is a salvage association and an association of underwriters who have their own respected and able inspectors to report on ships? Some of my friends tell me that the system in London is this:—An order comes to a broker to insure a certain amount on the hull or cargo of a certain ship. What is the operation? I ask Mr. Fenning to challenge my statement if it is inaccurate in any particular. The broker goes at once to the leading underwriter thinking, "If I can get Mr. So-and-So's name down my business is done." And why? Because all the rest of the underwriters, who are eager to follow like so many sheep, say to themselves, "I see Mr. So-and-So has looked into it, and it is all right." But Mr. So-and-So has not looked into it, and it is all wrong—and then all the rest of the gentlemen follow with their names for £50, £100 or £200. It is the old story, and what do they do? They do not say, "I neglected my own business and have been hanging upon a broken reed, and I will not do "so any more"—but the cry is for Government interference. I challenge Mr. Fenning to say whether that is not the system.

Mr. Fenning: Yes.

Mr. Lamport: I am an underwriter in Liverpool, and I venture to say I have been a successful underwriter. The system which is adopted in Liverpool is different from that in London. In London the broker goes into a large room and gets the leading underwriter to put down his name. He says, "Will you take a line on this ship?" And then if one will not, another probably will, and whether it is good, bad, or indifferent, they care nothing. That is not the system at Liverpool. The system at Liverpool is that every broker has his special *clientelle*. For instance, my name is in the hands of a respected firm in Liverpool, who when they receive an order for an insurance upon the hull or cargo of a ship, have to consider the interests of all those friends who, with perfect confidence, put their business and their prospect of profit and loss into their hands. Now, what is the result of that, and the principle of it? Confidence and responsibility; not law; not outside coercion or anything of that kind, but that which should be the true spirit and principle of all business, *viz.*, confidence and responsibility. These brokers in Liverpool attach the names of their friends, and they feel that for every £100 they commit one of their

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friends to in underwriting his name to the order they have got, adds to the moral responsibility which they have cast upon them of seeing that the risk they are running is a fair one; and I must say, that, as a rule, they attend to that,—and, therefore, underwriting in Liverpool is very different from underwriting in London. When I was a shipbuilder, and imported timber from abroad, I never could get my brokers to take the risks upon those timber ships. I always sent to London to insure these cargoes, and they were always taken at once without the slightest hesitation. If I could ever get my friends in Liverpool to entertain such risks at all, it was at such a rate that I could not afford to pay, whereas, if I sent them to London they were taken at once at a low figure. I want to know who is to blame for that—is it the shipbuilder and shipowner? Let me recur to my own experience as a shipbuilder. When I began shipbuilding, I did it because the business I was engaged in was one that did not suit my health. I was fond of ships, and shipbuilding was my hobby. I wanted to build the best ships I possibly could. I built ships for a few friends of my own, and I said: If you will give me a little more money, I will do this and that which will be an essential benefit to the ship. They patted me on the shoulder and said:—"My dear sir, "it is no use your doing anything of the sort, because we cannot pay you for it; nobody would pay us "more freight for it, because the freight depends upon the ship being classed A1 at Lloyd's." As to insurance they had no anxiety about that, for if they got the ship registered A1 at Lloyd's that was considered. I wish to ask you, Gentlemen, whether anything could put a more complete stop to progress in shipbuilding, leading to the preservation of property and life at sea, than this lax system of insurance? Mr. Fenning is the representative here of the London underwriters, and as I do not like to say anything when a person's back is turned, I am glad to be able to say now that the greatest part of this mischief—this scandal—this imputation on the business reputation of men connected with the commerce of England, which has been exposed by Mr. Plimsoll's manly and energetic efforts during the last two years, if it be at the bottom of the loss of life at sea, is to be charged not generally upon insurers, but upon the loose way of doing insurance business in London.

Mr. J. D'Aguilar Samuda, M.P.: My Lord and Gentlemen, I think that the Meeting will agree with me that we are only in this Institution interested in the matter of underwriting, and the connection between underwriters and shipbuilders to the extent and in the hope of producing a better state of things than that which exists; and I think that the observations which we have just heard will convince us that if we are sufficiently active in our search we ought certainly to find a way of improvement somewhere, because it is quite clear that a great laxity exists at the present moment which wants curing. When the matter is brought before us in the form in which it has been in this Paper, which I must confess I listened to with a great deal of interest and pleasure, and which conveyed to me a great deal of instruction, the conclusion I came to in my mind was, that unfortunately the insurance of this country partakes to too great an extent of that which the manufacturing industry of this country has partaken of for the last generation. I do not mean to put it in the slightest degree offensively, but I shall explain it more clearly than I could by any words of my own, if I state that for the last generation we have all been taught to accept the Manchester rule of commerce, which is, to regard price and price only as the quality we are to look after. What we have to do in this Institution is to endeavour to educate the public mind, as far as regards ships and insurance, so that they shall abandon that mistaken notion into which they have fallen, and revert back and depend wholly upon that much greater safeguard that we used formerly, and which our ancestors always relied upon, namely, character and not price. That is the beginning and

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the end of the whole subject. How does it work with regard to insurance from such points of view as have been presented by Mr. Fenning and corroborated by Mr. Lamport? How does it present itself to my mind, which is perfectly uninitiated with regard to the question of insurance and perfectly uninterested in it as a matter of general importance, further than desiring that it should act profitably to the community generally? How does it present itself to my mind that this thing works most disadvantageously to those who think fit to use it in its present form for the benefit of themselves and at the expense of the community? In this way:—Competition, as both of these gentlemen, who know so well the influence upon trade, have told us, is so excessively strong that it has to be met in some way or other. Trade gets bad, and freights fall, and two shipowners appear before the public, each of them desiring to work his ships. The freights are so extremely low that the scrupulous shipowner finds that when he has put into his ship a suitable cargo to insure her making a safe voyage, nothing is left for him, and it is a question whether he will lay his ship by or let her go to sea and just maintain herself, but do nothing in the way of profit. The unscrupulous shipowner, on the other hand, is not content to do that, but says, "I can get no more "freight than my friend, but I will put 200 tons more cargo into the ship, and if my ship gets safe into "port, and I get 30*s*. a ton extra for the goods, then I shall have £300 in my pocket. It is perfectly true "I know I am running a risk of making the ship unseaworthy to a considerable extent by putting it so "deep in the water, but I will go to Mr. Fenning, who will get the name of some of these good gentlemen "into his policy first, and then others will follow, and thus I can insure the ship for £2,000 more than she "is worth." Then what happens? The scrupulous shipowner must give in, and then the other goes on continually wagering either too much upon his policy or his over-freighted ship. Can anybody say that that is a state of things that an Institution like this, whose object is to improve the general character of the trade of the country, ought not to endeavour to correct? It appears to me decidedly a case that ought to be corrected. I quite agree that there are a great many points in legislative interference which are most dangerous, and ought to be totally disregarded; but I do think that every effort ought to be made by every ingenious suggestion that can be brought forward, to encourage and educate the public mind up to the knowledge and belief that by a sound, and wholesome, and honest trading, they must ultimately get greater benefit to themselves and to the public also. Then looking at it from that light the greatest importance attaches to the suggestion which has been made by Mr. Clifford Wigram. I cannot think that there is any point that touches so closely and so immediately upon the correction of this great evil which we are all now suffering from, as doing away with that system which he has referred to. What is that system? Why, it is this:—He puts it in a technical form, and I should not have understood it, except that I had had the advantage of being in his company for a considerable time before I came down here, and I had it more clearly explained to me. It is this:—A man has £100,000 worth of cotton to send home from India, or the same quantity of tea to send home from China. He sends over a notice to his agent in London—Insure this £100,000 worth of cotton for me in a ship or ships. That means to say in any ship that he thinks fit to send them in, and the name of which he does not at that moment reveal; and that habit has grown up, and has got quite common in London, and I believe not very uncommon in Liverpool, although I am not sure. Well, what takes place? They offer you in the first instance a ship of known responsibility; a ship of such a character as one of Green's, or Wigram's, or one of unimpeachable character, and the underwriter takes the risk under the impression that he is going to receive the rest of the goods in equally good and well-found ships; but when a bargain is once made the underwriter's hands are tied; he cannot exercise his own judgment as to whether he will accept the ship or not; but he

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has made his bargain, and, therefore, he must bring home the remaining £90,000 worth of goods in whatever ships are offered to him, and the consequence is that the owners with bad ships, finding they do not fill well, offer freight at a cheaper rate than the good ones, and he takes the goods in bad ships because he has the security of knowing that he can bring them home at the same rate of insurance as that which he would have paid if he had brought them home in good ones. That is extremely wrong, and if that system were discredited altogether, and if it were made a distinct bargain of trade by an association among the insurers that their judgment would only be recognized, and that they would take each policy upon its own risk, then the moment the inferior ship was offered, the price of insurance would be raised, and you would get before you in a very different form that which appears so palpable when it is put before you in the perfectly true form in which Mr. Lamport has stated, but which I will venture to put before you in such another form as to show you a wholly different phase of it. He tells you that only something like 5 per cent. of the ships have been lost of those that have gone to sea through unseaworthiness.

Mr. LAMPORT: Four and a half.

Mr. SAMUDA: Yes, 4½ per cent. of the total average; but there may be a large number of particular owners who, instead of 4½ per cent., have lost 24½ per cent. of their ships; and you are making those persons who produce good ships—who are conscientious men—who have got good materials in their ships, and good crews, pay for all the difference of this 24½ per cent. that went to the bottom. That is really the case. There is nothing so deceptive as averages, although there is nothing so good, if all the cases are alike on which you base them. These are things which we require to have put right. If you could, by some such course as that suggested by Mr. Wigram, prevent the possibility of the good paying for the bad, by allowing a bargain which should class them altogether in one contract, and prevent the underwriter from complaining, at least, you might have one advantage, which cannot be put forward by those who, like Mr. Lamport, possess so intimate a knowledge of insurance that he might have assisted us in this matter in a much better manner than I can assist you; but that is one of the points which I think it most important for you to deal with. Now, I am not certain that the scheme which has been shadowed out, of all these insurance offices throughout the kingdom uniting together on so large and grand a scale, would be an unmixed good. I am rather inclined to think it would have very much the effect which the combination of coal owners had upon the public, when they all united together and charged us £50,000,000 more for coal in 1872 than we paid in 1871.

Mr. LAMPORT: The suggestion was that the Register Offices should be united.

Mr. SAMUDA: It is the same thing, because they represent the others. I think there is a great deal of good to be got from the being able to form so much of an union as would enable them to feel confidence in themselves to reject that foolish and ruinous competition that nine-tenths of the trades in this country are suffering from, because they have not got a sufficient amount of reliance upon themselves to separate themselves from that which is doubtful and bad, and to cling only, and to be content only, with that which is good. They grasp after too much; and this would enable them to take a much fairer and much fuller view of the case. I think we should be very much obliged to Mr. Fenning for the Paper, because I do believe, myself, that there does lie in that a great deal of the ground-work which, when well considered and worked out, would be of the greatest possible public advantage with reference to insurance.

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Mr. W. W. RUNDELL: Before joining in the Discussion on this Paper I would make one remark. I am not going to reply to the question which was asked of the gentleman who read the Paper, but I intend to refer to it by saying that none of the witnesses before the Royal Commission who represented the Liverpool Underwriters' Registry made any remarks of the kind which he quoted, although he seemed to say there were three societies which had combined to give the same evidence. To go to the general topic, the key-note of the whole appears to me to be the Plimsoll agitation—the appointment of the Royal Commission and the Legislation that is now imminent in consequence of their Report. The subject divides itself into two parts; first, the Legislation as regards the shipping laws, and next as regards insurance. My first observation will refer to insurance only. Yesterday we heard it distinctly asserted that insurance was at the bottom of the whole question. It was said that the value put upon ships was excessive in many cases, and that this over-insurance on ships led to their loss. It was also asked at that time how are you to value ships? There are several values; there is the value to the owner; there is the market value; there is the value that was paid for the ship, and there is a fourth value when the ship has to be sold at an unfavourable time and you are obliged to take an auctioneer's value; and then again there is the policy or contract value. Now, I believe we shall be obliged in this matter to confine ourselves to the contract value, no matter whether it is over the market value or the auctioneer's value,—no matter what it is. I think there are reasons why we should keep to the contract value as put in the policy of insurance. It almost resolves itself into this as a matter of necessity. Is there any need of Legislation to protect the shipowner and the underwriter in fixing this value? Is it not sufficient to let them make their own bargain without interference of any sort? Next comes the subject of insurance on freight. Now, any one in looking through the Report of the Royal Commission will see that while incidentally the values of the ships occasionally were introduced, the main part of the evidence went to show that freight was the principal topic; because it was stated that if a ship were lost at the beginning of the voyage there would be a decided profit to the shipowner in getting the whole freight without having gone to the expenses incident to the whole voyage. But that really is a small matter, and I think might be easily dealt with by making the freight policy one of indemnity only. So much for that part of the subject. Let me now go one step further. I come now to the topic that has been very much discussed here, and which still, I think, shows many points still open for discussion. It is stated in the Amended Bill that Legislation that we are to have with regard to shipping must include some sort of classification, and I intend to argue (though I believe it has been opposed here this evening) that this classification, is outside of and has nothing to do with the existing registers of shipping. This classification is a necessity in consequence of what? In consequence of the Legislation of 1873. That Legislation really gave the Board of Trade power to class ships without giving any rule or basis for classification. What is their system? They have surveyors at different ports who send them letters and telegrams daily, saying how certain ships are being laden, and whether they are getting deep or too deep. Shipowners are now subjected to this almost intolerable surveillance—they are being watched to see how their ships are laden. The reports come up—"Such and such a ship is getting very deep," and the question is whether she shall be stopped. Now the surveyor at the out-port, is possibly a man without experience who knows nothing about the construction of the ship or her relative strength, or what class she has at Lloyd's or anywhere else, yet in an *ad captandum* manner, without knowing much of the profession of shipbuilding, without perhaps having seen the ship before, he has to judge of the strength of the ship, and how much she can carry. Is it reasonable or fair to the shipowner that this should be the case? This, in fact, compels the shipowner to say, we

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must, if we are to submit to this, have some sort of official tables of scantling, some rules of classification. This means classification outside Lloyd's and the Liverpool Registries, classification by the Board of Trade. You cannot stop short of that—at least, I do not see how you are to stop short of that; because there are at present no rules for the guidance of these surveyors. These are comparatively new men at their work, who are to decide as to the loading of ships. Yet they are supposed to know the strength of each ship and what she can carry. This leads me now to say that if the public require this classification, and if they require this supervision on behalf of seamen, it is really not because the ships are weak, but it is on account of the ships being badly manned, or badly commanded. Only 4½ per cent. of the losses are stated to have occurred from want of strength or from unseaworthiness or from like causes, the great mass of them comes from incompetency of some kind; and, therefore, you are seeking to protect men who do not care to protect themselves. Is this a fit subject for Legislation? Is it necessary to have Legislation upon it now? I think not. If the public go in for this, I think it as well that they should know they are going in for classification of ships by the Board of Trade, and nothing short of that. There is one other point to which I wish to refer. I could not help remarking yesterday when Mr. Brassey spoke so emphatically on the necessity of improved technical education on the part of those who commanded our ships and those who sail and work them, that this necessity really lies at the bottom of all our social and mechanical arrangements. This morning I am sure that everybody here must have been greatly interested in the way in which improved materials for iron shipbuilding were discussed. It was a most interesting Discussion, and well worth coming from Liverpool to hear it. In that Discussion it was shown that the more you improve the materials, the finer their quality, the more skill you require on the part of the artizan. This shows that technical education, general education, and above all, moral education, is necessary if you want faithful work in good strong ships, and these ships successfully navigated. It must have occurred to some that Mr. Brassey's remarks on another subject also bore very pertinently on this inquiry. Mr. Brassey's father having to construct railways abroad found that by giving the best prices to his workmen—that is, by having the most expensive class of workmen—he could do the work most cheaply. Good work does not mean cheap labour, but the most expensive labour you can get, that expensive labour being the cheapest in the end. Therefore, it seems to me, that all these points come back to this one thing—education, the raising of the general intellect not only of the working classes, but of all classes of the community. We must raise their scientific knowledge—we must raise their technical knowledge—we must raise their moral knowledge, and thus in the end, I suppose, we shall slowly arrive at Utopia.

Mr. Craven: I must say that shipowners now-a-days seem to have very few friends left. The underwriters want to combine against them, because they cannot make their business pay. If all Legislation is against the shipowners, I cannot see how they can possibly live. The rates of freight at present are very low indeed—in fact, ruinously low; and there is no doubt that at present, with the enormous number of ships that have been built, there is not likely to be any improvement. I believe the shipowners of this country, as a body, are as honourable as any other body of men. If they have a ship badly built, I do not say it is their fault at all, nor do I say it is the fault of the builder in many instances. Look what a time those gentlemen have had the last two or three years, during which there have been so many strikes. I think Mr. Fenning has omitted one important point which underwriters very often overlook, and that is the captain who commands the ship. I think one great evil of the present day is, that ships have been built faster than the captains have been educated to command

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them. In many cases a shipowner is obliged to change the captain of a ship, and it is almost like one man driving another man's horse. Collisions, in my opinion, very often arise from the fact that the captain does not know in how short a space he can bring the ship up; and collisions are one of the great risks which underwriters have now to contend with, and the more ships we have on the sea, the greater must be the losses *pro rata*. I think, if underwriters looked more to making occasional presents to captains for having meritoriously got out of all sorts of salvage cases and difficulties, there would be much more encouragement to captains, and we should get a better class of men to go to sea. Gentlemen around me know well, that when ships are long at sea, the captains occasionally have to burn some portion of their cargo, in order that they may complete their voyage, otherwise they would have to turn back, in which case the ship might founder. I hold in my hand a letter from the agent of one of the leading Insurance Companies, in which he suggests that underwriters should make some recognition of a captain's merits; and in the particular instance to which he refers, he recommends that a sum of £100 should be presented to the captain as meeting the justice of the case. I may tell you that in this case the ship was short of fuel; that tugs came alongside and asked different sums up to £1,000 for their services, and the captain in his peril offered them some £200 or £300, which they refused. He went further on, and before the voyage was completed, the tugs followed him, and then they offered to take him in for £12. I say that £100 reward to a captain in a case like that is an incentive to greater exertion on the part of those who get their living on the high seas.

Mr. Norwood, M.P.: I should not have ventured to have made any observations at this Meeting except for some remarks that fell from Mr. Rundell which require some notice. Mr. Rundell expressed an opinion that the carrying out of the powers of the Board of Trade in stopping and surveying ships necessitates a system of classification of ships by that department. Mr. Rundell has fallen into an error with reference to the powers the Board of Trade have received within the last few years with reference to the survey of ships. Classification, whether at Lloyd's, the Liverpool Book, or the Bureau Veritas, is a most useful thing, and is a test of the mercantile value of the ship. It lays down important rules as to the building of a ship; and the class given in those books shows very clearly the position of the ship at a certain given time, and her qualities for carrying different sorts of cargo. But the survey which is carried on by the Board of Trade, which power has been given them by the Legislature in the last few years, has no relation to the carrying of cargo, or any mercantile consideration. The powers given under the Act of 1871 and 1873 were merely with reference to the question of preservation of life at sea. What the Board of Trade has to consider, when it stops a ship or orders a ship to be repaired or lightened in its cargo, does not at all affect the safety of the cargo of the ship, but it is entirely with reference to the safety of the men who navigate the ship. With reference to the Legislation that is before us, I think we should do well to throw out of consideration all these ancillary subjects. Do not let us attempt to guide the course of affairs with regard to loss of life at sea by endeavouring to interfere with business details. Merchants, shipowners, and underwriters will take care of themselves. What we have to look to is the lives of those who navigate our ships.

Mr. C. W. Merrifield, F.R.S.: I should like to make briefly a few remarks on the general question of the interference of the Government with regard to the question of protection of human life, in that respect warning you that I am simply stating my own opinion. I quite endorse the opinion which has fallen from Mr. Norwood, that it is extremely unjust and undesirable, that Government, in attempting

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to legislate for the protection of human life should interfere with the usages of trade as a general rule. But it seems to me to be rather otherwise, if a case is made out (and it appears that we have heard a great deal to-night which goes far to make out that case), that certain mercantile usages do interfere with the safety of life. I will give you a parallel case, in which the Legislature has unhesitatingly acted in that direction, and that is the question of life assurance. Repeatedly persons interested in the direction of Life Assurance Companies, and in the management of them, have pressed upon the Government that they should repeal those rules of the Insurance Law which prevent a person recovering the sum assured on a life in which he has no interest. Now the Legislature, in spite of all applications and all pressure from actuaries of insurance companies, has invariably refused to do so, and for the simple reason that it would be murder made cheap, and it has declined to make murder cheap for the convenience (and it was very little more than the convenience) of investors in insurance companies. Now it seems to me to be perfectly established that there are certain cases in which vessels go to sea over-insured and are lost in consequence. I do not say they are deliberately over-insured with a view to their loss, but that they are so over-insured that, as Mr. Samuda very wisely observed, the owner stands to win on the insurance if he loses his ship, and on his freight if he does not. It cannot be said that he has that reasonable interest which a shipowner ought to have in securing the thorough seaworthiness and proper navigation of a ship, and I think the Government, or the Legislature, is entitled to say, all mercantile usage and convenience to the contrary notwithstanding, that it will, if it thinks it proper and wise to do so, decline to recognize any bargain which goes beyond mere indemnity, reserving to itself, in its own wisdom, the question whether it will abate the contract altogether or simply decline to recognize it beyond the indemnity. There still remains the question whether it is wise, and whether it is possible to do so. Those are questions which I do not intend to enter upon; but the moment you have made out that even occasionally a state of things happens in which a man has an interest in risking life, or at all events no interest in preserving it, then it cannot be said that the Government has not a right to interfere merely because it may disturb some mercantile usage or convenience. If mercantile usage or convenience stands in the way of public weal, one or other must give way, and I do not think there can be much doubt which.

Mr. W. M. Fenning: In venturing upon the somewhat troubled waters in which the whole of this question seems to float, I should like it at first to be very clearly understood that in anything which is said, I am sure there is no desire on the part of the underwriters or of many of those who are, as it were, conducting an agitation on the present subject, to indulge at all in class recrimination. I feel there is a tendency sometimes on the part of many shipowners (and I am happy to say I have a great many among my friends) to say that those who speak upon this subject and who are endeavouring to stir up the public on the subject, are speaking against shipowners; and, although in the Discussion which has taken place this evening much less of that feeling has been displayed than occasionally has been the case, I feel there is a kind of rankling sore existing; and when I spoke as I did about the Register Books, although I was innocent of any feeling whatever, it may seem as if I had some sort of grudge and was speaking unjustly. Of course on a large question of this kind one is obliged to generalize to a certain extent, and when one asserts that some shipowners are not respectable one does not stigmatise the whole class. In the same way when one says many underwriters are very foolish, one does not mean to say that they are all fools. I will now mention one or two points which have been touched on by the eight gentlemen who have spoken in this debate. In the first place, in reply to the remarks of Mr. Clifford Wigram and also of Mr. Samuda on the

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subject of open policies, I would suggest that this is a subject which it appears to me is not quite clearly understood. All merchants know, and I now speak as a merchant, that practically speaking these open policies are a necessity to commerce. I do not see myself, looking at the point as a merchant simply, how I could insure my produce coming home unless I had open policies. Assume that I have a lot of cotton coming home from the Brazils, without having the smallest idea what ship or steamer it is coming in, of course I do not wish to run that great risk, but if I have £50,000 worth of cotton at this moment purchased to come over here, part of which may be afloat, I do not know how much of the cotton is afloat. I have not the remotest idea, and I do not know in what ships it is coming. The agent can telegraph he has shipped by such and such a steamer, but the telegram may be delayed, and the steamer may be lost going out of port—such things have happened—in which case the merchant would be uninsured. I would venture to say with regard to open policies, if you were to take the sense of the mercantile community all over the world, they would all agree it would be found very difficult to cover themselves by insurance without the aid of open policies. With regard to the indiscriminate character of ships included in open policies, I know that, as an underwriter, I frequently write ships home from Bombay at 40*s.*, returning 4*s.* 9*d.* for Green's, Wigram's, and other well-known ships which I thus write at a cheaper premium—so that there is upon open policies a cheaper premium for the good ships, and a higher premium for the bad ships. I think it is clear that you do pay a higher premium upon open policies for an inferior ship than what you do for a superior ship. You may warrant in an open policy that the cargoes are to be shipped in A1 ships and so forth; but where the difficulty comes is this, that there is such competition among underwriters that very often they omit to provide themselves with this safeguard, rather than go without the risk. A says, if I do not write this without putting in this clause, B will, and so I must trust to Providence. I feel I ought not to allude to Parliament in this Meeting, but I noticed in the Discussion which took place the other day that there was rather a set made against open policies, and I thought to myself I wish there were a few merchants and underwriters in the House of Commons who would take the thing up, and show that open policies if not abused, are absolutely necessary for commerce. I have noticed throughout the whole of this Discussion that a great deal of stress has been laid upon the inefficiency of captains and crews. For my own part I do not think they are always to blame. There is a vast amount of blame often put upon captains which they do not in the least deserve. A notable case occurred the other day which I think was alluded to by the gentleman who spoke second, with regard to the *Soudan* steamer, one of the African boats, which was wrecked at Madeira. I noticed with great regret that the captain of that vessel was sentenced to one year's suspension of his certificate, and why? Because, so far as I could make out, the engines of that ship were in an unseaworthy condition. I may be speaking wrongly, but if there is any gentleman present who knows the ship or in any way represents the Company to which I refer, I should be glad to be corrected. I have traced that ship on her previous voyage. She broke down then, and a few repairs were executed in Liverpool before she started. After she started, the engines worked tolerably well, or I may say entirely well, till she got to Madeira; but when she got to Madeira and had anchored, and required to start again, the captain, before giving orders to go a-head, communicated with the engineer, who said, "all right." The captain thereupon gave orders to go a-head and the engines refused to move. The ship by this time had got close into the shore and was driven ashore, he having weighed his anchor. Why on earth that captain should be deprived of his certificate because of the unfitness of the engines I am at a loss to conceive. With regard to the difference that exists between the way of carrying on underwriting in Liverpool and in London I think a slight mistake has been made.

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What I wished to convey by my remarks was, that the general system of underwriting all over the world is defective, because the underwriters all over the world have no power of combination among themselves. That remark applies equally to London, Liverpool, Glasgow, Paris, Hamburg, America, and, indeed, to all places where insurance is carried on to any great extent. It is a common thing if you cannot get an insurance effected here on good terms to send it over to Paris, or elsewhere, because if anything is known against a vessel the Paris or other underwriters are perhaps not aware of it. But the Paris underwriters often communicate with the London underwriters. I received a letter from a Paris underwriter the other day asking me for information respecting a claim upon a ship which he was interested in. I had no personal knowledge of the case in question, but tried to find out something about it for him, and after fruitless efforts was unable to do so. He then wrote over and said:—"If you had asked me for this "information in Paris, we have a certain amount of combination among underwriters which would have "enabled me to have obtained it for you, but in England you have a very lax system, and in consequence "of that you cannot get any information." What I have proposed is, that there should be an organization established among the underwriters which would take in the underwriters of London, Liverpool, Glasgow, and, in fact, have ramifications. That would not be, as has been suggested by one gentleman, an organization or combination to raise premiums, but simply a combination to secure common action on the part of underwriters, to record their various experiences, to enable them—by recording those various experiences—to avail themselves of an experience extending over a large basis, instead of having to trust to the small experience which is gained in their own particular little circle. That would lead to uniformity among them as to settlements, but not as regards premiums. The risks they would still be legally liable for, but they would have greater power to go into the courts of law, if necessary, and they would be able to have a combined sort of committee, who would dispassionately and calmly go into certain questions for the general benefit of the underwriting body—not a few captious underwriters endeavouring to dispute this or that claim, but a dispassionate body who could go into the question of what underwriters generally ought to pay. Do not imagine that I am speaking on the underwriters' behalf; I am only speaking on this point as it bears upon the main question before us, namely the safety of human life at sea. This sort of combination would, I think, give power to the underwriters to insist that the contract they enter into should be carried out, namely, that the ships should be seaworthy, and if the ships were seaworthy the security of the public would be very much more provided for. As I have said all along, if the underwriters are able to do this—and, if they set their minds to work, I believe they could—it would be a great benefit; but if they do not, then I would say let us have Legislation. I would rather not have Legislation, if the underwriters could be induced to combine; but, if not, I believe, myself, that the only thing is Legislation, because such an evil as has been brought before this Meeting must be checked in some way, and if not by private means it should be checked by public means.

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ON THE STRAINS AND STRENGTHS OF SHIPS.*

By JOHN WIGHAM RICHARDSON, Esq., Member.

[Read at the Sixteenth Session of the Institution of Naval Architects, 19th March, 1875; JOHN SCOTT RUSSELL, Esq., F.R.S., Vice-President, in the Chair.]

I HAD occasion last year to publish some observations upon the evil effects which the wrongly based rules adopted by Classification Societies are exerting upon the art of shipbuilding.

It seemed to me then, as it does now, that the losses of ships at sea have been greater than what can reasonably be accounted for by perils of the sea or by bad navigation. I wished to point out, that when rules of construction are framed upon false or incorrect principles, they may become almost a premium upon bad models, low freeboards, and deficient strengths. Ships are built to earn a profit, by carrying for hire passengers or goods; and, if one form of ship will carry cargoes more cheaply than another form, there will always be an inducement to adopt *that* form which leaves the highest dividend. Often—nay, in fact, usually—these inferior types are adopted in perfect good faith. A shipowner finds that one of his ships pays better than another; he seeks for a reason; and discovering that the one ship is longer and fuller than the other, and yet costs less in proportion to the freight earned, he orders a ship yet longer and yet fuller.

A very interesting Paper was read, last year, by Mr. William John, upon the relative strengths of steamers of different tonnage. I presume they were all "classed" vessels, as he did not state the contrary. He stated therein, that, as at present built, "the "tension per square inch on the upper works of a vessel of 3,000 tons appears to be "one and a half times as great as that on a 1,500-ton ship, twice as great as on a "700-ton ship, and five times as great as in a little vessel of 100 tons, of the same "proportionate dimensions."

* Received 20th February, 1875.

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These results certainly were a surprise to many, and so (if I may venture to say) were the semi *laisser-faire* conclusions with which Mr. John closed his Paper; but this one reflection, at least, must have occurred to all—*if Mr. John's Society pretends to investigate the respective strengths of ships, and give different classes for different qualities, how can it assign the* same *class to vessels of such disproportionate strength?*

If all ships were built of the same strength, I do not think that this advantage of better dividends would lie with the inferior type, nor (at least not to so great an extent) with vessels of increased size; and it seems to me that such Societies as Lloyd's, the Underwriters, and Veritas, have a duty to perform in seeing that this tendency shall not be allowed to exist.

In the rules of these Societies it appears to me that there is sometimes an absolute confusion between what constitutes a *strain*, and what is really an element of *strength*. In other words, a *factor of strength* is sometimes confounded with a *function of the strain*, or, as it is now often termed, of the *bending moment*. From this it arises in certain classes of ships that a little extra freeboard is the most expensive luxury which a shipowner can indulge in.

Nobody can think that such a state of affairs is right. It cannot be to the advantage either of the Societies, or of underwriters, or of shipowners, or of merchants, or of shipbuilders, or (lastly, and most important of all) of seamen.

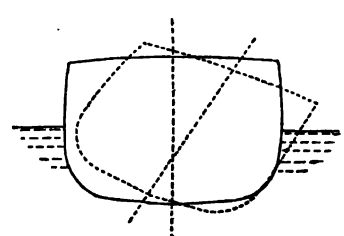
The little publication to which I refer called forth a large amount of concurrence with the views which I ventured to express therein, and I have been asked by one or two friends, and one or two correspondents personally unknown to me, to state definitely what I conceive to be the true way of apportioning the strengths or scantlings of ships. This I am very willing to do; and in putting these views in the form of a Paper, to be read before this Institution, I am assured of having an audience capable of approving or of condemning. At any rate, I may hope to evoke an intelligent discussion, and, in the spirit of old Horace, I may ask you if you know anything better, candidly to impart it, if not, to make use of this which I lay before you.

If you will allow me, I will confine myself to iron ships, and first set forth the practice of my own firm when we build ships which are not to be classed, after which I will venture to point out a basis which I think might be adopted by Classification Societies.

Let us take the strains of a ship at sea, as of three kinds, *viz.*:—

1.—Tranverse strains, such as affect a ship when she is heeled over, and which tend to alter the midship section, thus—

Fig. 1.



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2.—Local strains, such as the impact of waves.

3.—Hogging, sagging, and side strains, regarding the ship as a hollow beam, or as a girder.

There are also the strains of torsion; but these need hardly be gone into, since they are resultants of transverse and longitudinal strains.

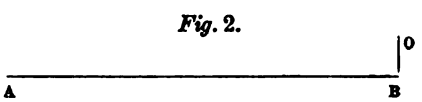
Now I would remark that the first kind of strain, the tranverse strain, is greater in a sailing ship than in a steamer. The strength to meet this strain is most effectually applied by introducing bulkheads; and it is curiously worthy of note that the usual practice is to provide bulkheads in steamers, and, except at the ends, to omit them in sailing ships. In the absence of bulkheads, the necessary strength is attained by beam knees.

The second class of strains, which I call local strains, must be proportioned to the *weight* of the ship, which is, of course, equivalent to the *displacement*. The calculation of the displacement is the first which the builder makes, and it comes most conveniently as the true basis for strains. Comparing a small ship with a large ship, it may be doubted whether the force of waves is greater in proportion to increased weight of hull. For instance, does a wave strike a ship weighing 4,000 tons twice as hard as it strikes a ship weighing 2,000 tons? This is a question which leaves room for some difference of opinion; but we may, at any rate, safely assume that the wave impact against a ship of 4,000 tons displacement will not be more than double that against a ship of 2,000 tons. The exact strain is, perhaps, beyond our powers of calculation, and we regard it as legitimate to form a conventional scale of scantlings for varying displacements. This scale is lighter than the rules of the various Societies for small ships, but does not differ greatly from their rules for larger ships.

We also consider that chain cables and anchors should be based upon the displacement: that if one vessel is twice the weight of another, it should have cables of just double the strength.

Having now determined the minimum thickness of plating, we draw a line, A B, half the length of the ship; and upon B we erect an ordinate, B O, which on some convenient scale represents the number of square inches of the shell plating and gunwale stringer, 4 or 5 feet abaft the stem.

Fig. 2.



The next step is to estimate on the sheer plan the centre of gravity of the fore body

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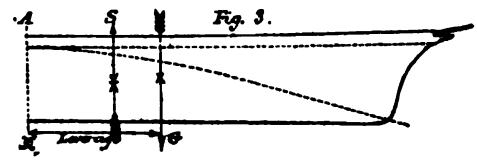
when the ship is loaded with cargo. This is done in the usual way, by calculating, first the centre of gravity of the hull, then of the cargo and machinery spaces, and finding the mean in proportion to the distance from the dead flat. This centre of gravity of the fore body is marked on the plan, and the distance from the dead flat is the leverage A G.

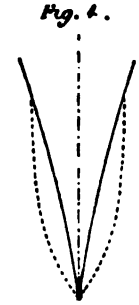


The strain (or, as it is sometimes called, the bending moment) will be the displacement or weight of the fore body multiplied by the distance of G from A. This is supposing the vessel to be supported in mid-air on a fulcrum at A.

We must now consider what is the strain when the ship is water-borne; and, in so doing, I would allude to an assertion, not unfrequently made, that fine ships more frequently show signs of weakness than ships built, say, like boxes. I have heard surveyors of experience assert this as a fact which has come under their immediate observation. My own experience leads me to quite an opposite conclusion. We have frequently had to put new engines into ships built twenty years ago, with fine lines and with scantlings very much less than what are now in vogue for their dimension; and I have often been surprised how staunch and good they appear. I fancy the surveyors who made these observations did not make the distinction between *long* ships and *fine* ships. A very long and fine ship, with her scantlings based upon the simple product of her three dimensions, and made unwisely heavy at the ends, would, indeed, be very likely to show signs of weakness.

Look at Fig. 3, and imagine the dotted line to represent a wave. It is a matter of easy demonstration by figures, and it is apparent by mere reflection, that the bending moment downwards of the prow must be greater as the vessel is made fuller forwards, or as the distance A to G is increased by shifting the centre of gravity forwards. The full part forward is *not* water-borne; but, by the very supposition of the calculation, is left bare by the depressed wave.

It is quite true that if the ship has what is called a "long floor" there is a better support; that is, if the forward frames are made fuller towards their base (*see* Fig. 4). But this particular fulness will probably always be carried out as far as practicable. Again (*see* Fig. 3), imagine the wave to be suddenly reversed, it is only too evident that the finer ship will receive a less violent shock than the full ship, and that thus the sagging strain will be less. In practice, I believe that the bending moment will vary pretty nearly in the proportion of the length multiplied by the displacement, but I will



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recur to this further on. In the meantime we consider that one-third the strain in mid-air is very nearly what the actual strain is when riding on waves. This is, taking a wave curve from the gunwale amidships down to the fore foot (*see* Fig. 3), which is considered to be the form of a wave imposing the maximum strain, and we find that the centre of support S is usually at such a distance, that A S = $\frac{2}{3}$ A G, or thereabouts. In types of vessel such as my firm have built this proportion has been found to be approximately correct, and in practice we adopt it. In two steamers of nearly equal dimensions, the lines of one being fine, and everything in the design disregarded except speed; the other being, on the contrary, a full vessel, designed to carry a certain load on a limited draft, I found the following proportions:—

First Ship.—Co-efficient of fineness ·48 A S = ·647 A G.
Second Ship.—Ditto ditto ·62 A S = ·7 A G.

And, considering how uncertain our knowledge is of the forms of waves, the proportion, two-thirds, which I have taken, will probably be considered a sufficient approximation. The respective co-efficients of fineness of the two vessels referred to are nearly the extremes of what is found in practice.

We have now arrived, by a very simple process, and without any calculation beyond those which are familiar to all shipbuilders, at the strain or bending moment of a ship, regarded as a girder. Let us proceed to consider what is the weakest point of the beam; and, if we get this sufficiently strong, we may safely proportion the rest without calculation; I mean, without calculation in the same way as if we were calculating the strength of a cylinder—having found the requisite thickness of the barrel, the flanges and other parts follow naturally. Now, in a ship the breadth of beam is, I think I may say, always greater than the depth; and, since the strength of a girder varies as the depth or distance across—or, if the material be proportionately increased, as the square of the depth—it is evident that, with equal scantlings, the strength sideways will be much greater than the strength vertically; and further we may, I think, fairly assume, on the other hand, that the strains also *sideways* are much less than the *vertical* ones.

Again, comparing the upper member or flange of the girder with the lower—that is to say, comparing the bottom with the top—there are various considerations which will cause the bottom to be made the stronger of the two.

Firstly, the deck is cut up by openings for hatchways, for machinery, for entrances to cabins, &c., &c.

Secondly, the bottom is made stronger for other reasons, such as the weight of

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cargo and the upward hydrostatic pressure, and the practice of letting iron steamers lie aground, either bare, or partially water-borne; and,

Thirdly—at any rate, in steamers—the seatings or foundations for the engines and boilers are, or ought to be, made in such a way as very much to increase the strength of the bottom at the weakest point—that is, at the centre.

We must, therefore, direct our attention to the strength of the top of the girder. This may be calculated by the formula given by the late Sir William Fairbairn, which is based upon the square inches of section, and their distances from the neutral axis. Simpler and more ready approximate methods will occur to every one, and my firm is accustomed to use one which I believe to be sufficiently exact, but which I will not enter upon here, as I wish to avoid points outside of the special question.

There may also be a difference of opinion as to the proper factor of safety. We, ourselves, consider that one-fourth is as low as it is safe to go; or, in other words, that the bending moment should not exceed 5 tons per square inch of iron.

This is the factor of safety which Mr. John has found to exist in vessels of 1,000 tons, and I fancy it is but rarely that signs of weakness have been found in well-proportioned ships of that size.

Some twelve years ago my firm built a small steamer, the *Isabella*, for Russia, which afforded an experimental proof of the sufficiency of this factor. She was of very extreme dimensions, *viz.*, 140 × 14 × 6,—or 10 beams and over 23 depths. As she had to go under a bridge, it was not possible to introduce a hog-girder, such as we find used in the United States. Her draught of water was only 17 inches, and her plating extremely thin. Under these circumstances it is not to be wondered at that there was a difficulty in effecting the insurance, so that I determined to go out in her myself. She was to cross the sea to Danzig, thence up the Vistula and its tributary the Bug, and so by a system of canals to the upper part of the Dnieper, finally ending her voyage at Kiev—where I believe she is still doing good work.

The scantlings, though very light, were duly calculated, and though we had very rough weather on the voyage, I do not think any of the ship's company had any fear except the chief engineer, Mr. Cardigan, who laboured under the hallucination that one of the bottom plates had been strained and cracked across, and that he could see daylight through it. In the Baltic we encountered a severe storm, and along with about fifty other vessels, some of them large steamers, we took shelter under the lee of Bornholm; but of these fifty vessels we were the very first who put out again to sea.

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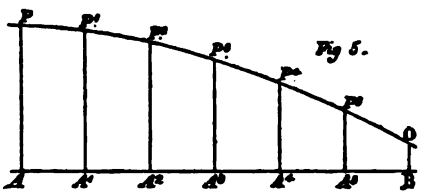
In ascending the Vistula we repeatedly grounded, and afterwards she fairly stuck on a sand bank in the Bug. All efforts to get her off were fruitless until, at Mr. Cardigan's suggestion, two large trees were cut down, and a pair of shear legs let astride our ship. To these the main cable (a $\frac{5}{8}$ short-link crane chain) was lashed, and a turn taken round the paddle shaft, the engines were started, and the vessel was lifted up bodily some 6 inches. Then with the winch, or windlass, she was forged ahead a few feet. This operation was repeated several times, until she was clear of the sand bank.

The shear was not broken, and our calculations were justified.

To resume: having now arrived at the scantlings of the upper portion of the girder, we fix those of the sides and bottom conventionally in proportion, and then we find the number of square inches of section at the midship girth, and taking the line A B, Fig. 2, we erect an ordinate A P, Fig. 5, representing the square inches of section amidships; and from P to O we draw a parabolic curve P O. We then at various points of the length measure the ordinates A_1P_1, A_2P_2, A_3P_3, &c., which represent the proper amount of section at the points in their length, A_1, A_2, A_3, &c.



It is of the very greatest importance that the scantlings of a ship should be evenly and gradually tapered. *It is the nick that breaks.* Suppose a parallel bar of iron 1 inch in diameter in the centre (Fig. 6), it will be evident to all that it will merely weaken it to add thickness as in (Fig. 7), while it is equally evident that it will increase the strength if it be turned down at the ends (Fig. 8) like a ship's yard.

Fig. 6.

Fig. 7.

Fig. 8.

In the same way a girder of plates made as in Fig. 9, is stronger than a parallel girder of equal depth at the centre made as in Fig. 10.

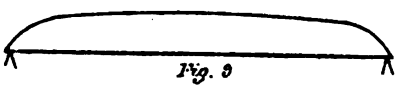


Fig. 9

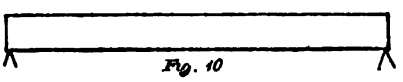


Fig. 10

Again, a lattice girder constructed with diagonals closer in the centre (Fig. 11) is stronger than one with the diagonals equally spaced as the closer distance (Fig. 12).

Fig. 11.

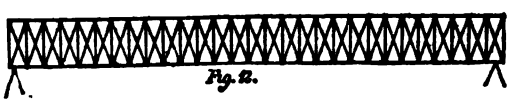


Fig. 12.

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Further, it is known that the strength of bolts is increased by reducing them to the thickness of the bottom of the thread. Thus of two bolts (Fig. 13) the one which is turned down is the stronger of the two, and not only the stronger, but, especially in resisting shocks, very much the stronger.

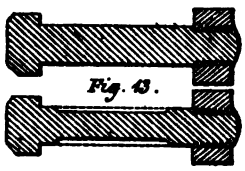
Fig. 13.

In the same way, a ship which has, for example, a long poop to amidships (Fig. 14), is not strengthened thereby, in any sense, but very much weakened at the point A, and that quite independently of the additional weight put upon the ends.

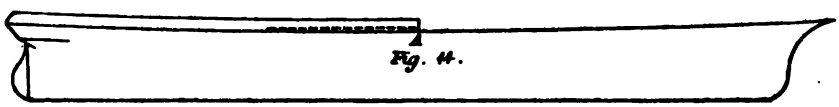
Fig. 14.

In fact, one way to strengthen such a ship, would be to cut away holes, as shown, filling them up in any convenient manner, or leaving them open, as the case might be.

Again, if we suppose the deck plan of a ship (Fig. 15), with a complete iron deck,

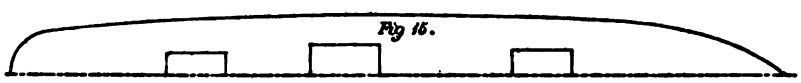
Fig 15.

that deck will be weaker, viewed as a stringer for longitudinal strains, than it would be if made as shown in Fig. 16.

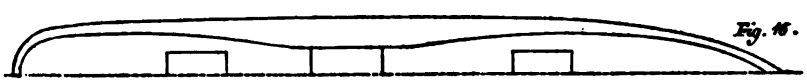
Fig. 16.

In 1866 Mr. Nathaniel Barnaby read a Paper before this Institution, recommending that the butt straps of iron decks should be omitted altogether, so as to secure the full elastic resistance of the iron. In most cases other considerations would probably deter a builder from carrying theoretic deductions to this extent, but the force of Mr. Barnaby's reasoning cannot be gainsaid.

The same considerations would, as regards stringers (in view of longitudinal strength only), lead to tapering them as much as possible, and even to stopping off some of them at a certain distance from the centre of the ship. Thus, when rules require *all stringers to be carried right fore and aft*, they positively weaken the longitudinal strength of the ship, and this weakening is aggravated by the additional weight with which the ends are thus loaded, and doubly so when we consider the difference in girth between the midship and the forward frames.

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To sum up the foregoing I may say that, in proportioning the strength of iron ships—

Firstly, the general scantlings, as also the anchors and chains, should be proportioned to the displacement, *i.e.*, to the total weight of the vessel and cargo.

Secondly, the strength of a ship, as a girder, should be proportioned to the product of the displacement and the distance apart of the centre of weights of the fore and after bodies divided by the depth of the girder, or

$$\frac{\text{Displacement} \times \text{distance of centres.}}{\text{Depth.}}$$

I now request your patience while I submit what I conceive would be a great advance in the practice of Societies in framing their rules. It will be evident that, from my point of view, no proper proportioning of ships can be obtained without ascertaining the displacement. This of course involves the fixing of a load line. The objections against fixing by Act of Parliament an arbitrary scale are patent to all, and it is improbable that any of the Registration Societies are prepared to take this onus upon themselves, nor is it advisable that they should do so. But please bear in mind that the question which I am now discussing applies merely to ships yet to be built, and I can hardly conceive any owner ordering, or any builder designing a ship, without forming some estimate of the proper load line. Recently, in what are called "Awning-deck" ships, Lloyd's Register has introduced the system (which seems an excellent one) of stating the load line in the Register Book. Mr. Martell, their Chief Surveyor, has prepared some valuable Tables, showing the surplus buoyancy with different degrees of fineness, and with different amounts of freeboard. Mr. Rundell, of the Underwriters' Registry, has read Papers before this Institution upon the same subject.

Bearing these instances in mind, I venture to suggest that when the plans of a ship are submitted, with a view to classification, the builder should furnish a shear plan, *with the intended draught of water and the displacement marked thereon*, and at the same time, or subsequently, a certain number of sections with the calculations of displacement, and that this displacement should be the "number" regulating the minimum scantlings. In case it be objected that a Registry Society must not accept mere plans, but must always certify by actual inspection, let me point out that, considering how surveyors are now expected to verify every detail of scantling by actual foot-rule measurement, there could be little additional trouble in measuring (during building) the frames, so as to see that they corresponded with the submitted plans. These measurements might also be taken on the laying-down board. Further, an additional check is available from the

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register tonnage, as set forth in Mr. Martell's Paper. The longitudinal strength should be proportioned by a rule which I will explain further on.

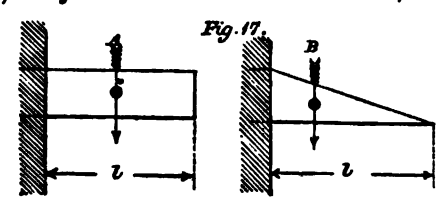
This submission of a load line I would make entirely optional, and owners might build in the meantime to the present rules, if they preferred to do so, and if the said rules were still considered safe for ordinary ships; but if the proposed new basis were taken advantage of, I should propose:—Firstly: To state in the Register Book what the load line is. Secondly: To mark it on both sides of the ship amidships. And, Thirdly: To state in the Register Book the proportion of surplus buoyancy.

If this were done, it must be admitted that the Underwriters would have a far greater protection than under the present system. The main lines of safety in a ship, *viz.*, the freeboard and a fair factor of strength, would be secured, and, compared with these, the present wearisome maze of details are of little importance indeed.

To revert to the proportions of scantlings to withstand longitudinal strains, the system pursued and the calculations made by my firm could not well be adopted, because the surveyors of a society could hardly take upon themselves to verify the centres of weights. Without doing this, however, they could, from the submitted plans, ascertain the centres of gravity of displacement; or, if that is too great a refinement, the following considerations will show that a fair approximation may be arrived at by simply multiplying the displacement by the length and dividing by a constant.

As I showed in the publication before referred to, if you take two cantilevers, A and B (Fig. 17), and suppose them to be of equal thickness, say thickness equal unity, then the weight of A is double the weight of B; but the strain on A is three times the strain on B. For if the weight of B be w, the weight of A is $2w$.

Fig. 17.



The centre of gravity of A is $\frac{1}{2}l$ from the point of support, and the centre of gravity of B is $\frac{1}{3}l$ from the same point; therefore the strain affecting A is—

$$2w \times \tfrac{1}{2}l = wl \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad 1.$$

Whereas the strain affecting B on the other hand is—

$$w \times \tfrac{1}{3}l, \text{ or } \frac{wl}{3} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad 2.$$

Or the strain on the one is three times the strain on the other. In reality the scantling required to withstand the strain would be more than three times, because the cantilever B more nearly approaches the true form for strength.

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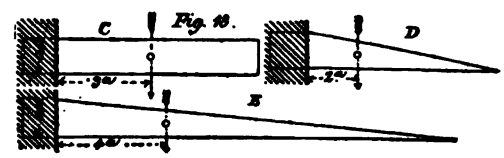
This I used as an illustration of the fallacy of proportioning scantlings according to the product of the length, breadth, and depth, and though an extreme illustration, it brings the question clearly before one's mind. In the instance which I have given above, from actual practice, the co-efficients of fineness differed as ·48 and ·62, or in other words, one ship was 30 per cent. fuller than the other, and, in this actual example, the difference of strains was 56 per cent. Lloyd's most recent regulations for extreme proportions would, however, have, I must say, corrected this to some extent.

But now (Fig. 18) take three cantilevers, C, D, and E, as before, of equal thickness, which we will call unity, (thickness = 1), and of the same depth a, and let us take the strains in terms of the *length* and *weight*, instead of in terms of the mere external dimensions.



In C the length is six times the depth, or $l = 6\,a$.

In D the length is six times the depth also; but

In E the length is twelve times the depth, or $l = 12\,a$.

The downward strain or bending moment of C is—

$$\text{Moment} = 6a \times a \times 3a = 18a^3.$$

But the weight—

$$W = 6a \times a = 6a^2 \text{ and the length } b = 6a$$

therefore—

$$\text{Moment} = W \times 3a = W \times \tfrac{1}{2}l \quad . \quad . \quad . \quad . \quad . \quad 1.$$

Similarly in the cantilever D—

$$\text{Moment} = \frac{6a \times a}{2} \times 2a = 6a^3$$

but—

$$W = \frac{6a \times a}{2} = 3a^2 \text{ and } b = 6a$$

therefore—

$$\text{Moment} = W \times \tfrac{1}{3}l \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad 2.$$

And in the cantilever E—

$$\text{Moment} = \frac{12a \times a}{2} \times 4a = 24a^3$$

but—

$$W \times \frac{12a \times a}{2} = 6a^2 \text{ and } b = 12a$$

therefore—

$$\text{Moment} = W \times 4a = W \times \tfrac{1}{3}l \quad . \quad . \quad . \quad . \quad . \quad 3.$$

These three cases are, like the others, very extreme ones, and yet we arrive at this, that if strains are proportioned as the weight or displacement multiplied by the length, the error in the most extreme instance possible will be as regards proportions of length

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to depth (D and E) *nil*, and as regards difference of fineness, only *one half* of what it would be on the system at present in vogue. In reality the error would be very much less indeed, and to give an example, take the two steamers before noticed whose displacement varied as ·48 and ·62, and I have found the error for impact strains to be *nil*—and for longitudinal strains to be between 5 and 10 per cent. only.

But W, or the weight, that is to say the displacement, is equal to—

$$\frac{\text{Length} \times \text{breadth} \times \text{draught}}{\text{co-efficient.}}$$

If, therefore, we multiply this by $\frac{1}{3}$ length, we have—

$$\frac{l \times b \times \text{draught}}{\text{co-efficient}} \times \frac{l}{3}$$

or—

$$\frac{l^2 \times b \times \text{draught}}{3 \times \text{co-efficient.}}$$

In other words, the strain varies, *inter alia*, according to the *square* of the length, which is strictly correct.

The proposed rule may be stated thus:—To find approximately the strain on the stringer line or upper flange of a ship, regarded as a girder, multiply half the displacement by half the length and divide by three. Then divide by the depth moulded; or, in other words, *multiply the length by the displacement, and divide by twelve times the depth moulded.**

$$S = \frac{\frac{1}{2}\text{ displacement} \times \frac{1}{2}\text{ length}}{3 \times \text{depth.}} = \frac{\text{Displacement} \times \text{length}}{12\text{ depth.}}$$

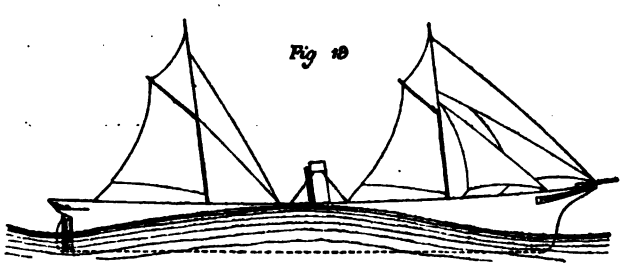
Fig 19

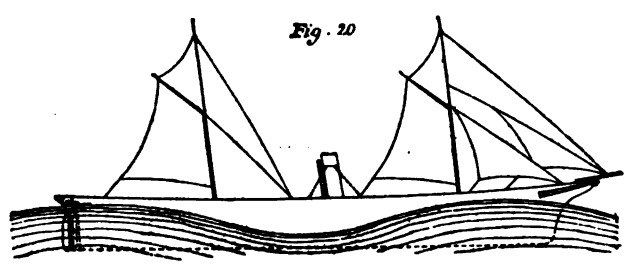
Fig. 20

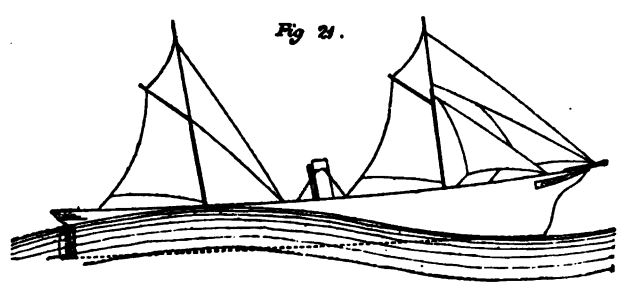
Fig 21.

* Mr. John's estimate of 1-35th for an ordinary merchant steamer differs from my figures very considerably. I understand he takes the strains which come upon a ship when stationary, thus (Figs. 19 and 20); whereas I suppose a steamer steaming across the waves and assuming the position sketched, thus (Fig. 21). If I am in error, I shall be glad to be corrected, for I can only go upon an assumption, since Mr. John does not give more than the *result* of his calculations. I am well aware that it is a fair question for discussion whether or not the extreme strain shown in Fig. 21 ever really does come upon a ship afloat.

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The strength to resist this strain will depend on the apportionment of iron in stringers, side plating, &c., and is to be calculated by the usual well-known rules.

In case of a ship being loaded with a poop or forecastle, an estimate should be made of the extra weight, and that multiplied by the leverage; and additional strength should be provided to withstand the extra strain.

It is evident, that, by fixing the load line and giving a proper factor of strength to the depth, the present distinctions which Lloyd's Register recognizes of three decks, spar decks and awning decks would very much lose their significance. The draught of water would be left to the reasonable option of the owner, and the strength of the structure would be taken on its merits.

From Mr. G. Moorsom's Paper, which appeared in the first volume of the *Transactions* of this Institution, I gather that his department would not object to adopt the displacement of a ship as the basis for register tonnage; and if this were done, every incentive to overloading would be done away with; for, unless owners wished to evade the very basis of their certificate of classification, they could have no sort of inducement to scrimp the freeboard. It would no longer be thought that until a ship was full she was not fully loaded. Deck loads would cease to offer much advantage. It would soon be found that more roomy spaces for seamen and for machinery might be accorded without any detriment to the freight. Extra depth, that is say, additional freeboard might be given, with positively an economy of material. A finer entrance or an easier run would not involve a ruinous extra weight. In fact, a ship would be designed as a *ship*, and not as a compromise between science and rules for classification. And, what I consider of the highest importance of all, you would not take off from the shoulders of the shipowner or builder any responsibility which ought fairly to be there. He would be called upon to fix his own load line; and, having fixed it, to stick to it, and to have the courage of his own convictions.

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DISCUSSION.

Mr. WILLIAM JOHN: As I had the honour of reading a Paper here last year on this subject, I should like to make one or two observations on the Paper which we have just heard. In the first place I wish to correct an error into which Mr. Richardson has fallen in assuming that all the ships with which I dealt last year were classed ships. I did not, it is true, say they were not classed ships, as I wished to avoid drawing such distinctions: but they included classed ships and unclassed ships, and I may say that the weakest ships to which I referred in that Paper were unclassed ships, and the weakest ship of all was an unclassed ship belonging to one of the large Ocean Companies. I do not mean to disparage unclassed ships, because I know there are strong and weak unclassed ships, but I wish to remove the idea that the gradation of strength, by vessels getting weaker as they get longer and larger, applied to classed ships solely, and not to unclassed ships. I may say as regards the present Rules of Lloyd's, that such a reduction of strength in large vessels as I pointed out, does not exist at the present moment. I will now pass to consider the mode of arranging the scantlings and strength of ships as proposed by Mr. Richardson, which he recommends for the adoption of the Register Societies. He describes the mode adopted by his own firm, and recommends something very similar. Now, in the first place, Mr. Richardson says that he finds what is the displacement of his vessel, and he bases the scantlings upon that. But if Mr. Richardson, as a builder, is building an ordinary mercantile vessel for any owner in the country, after it leaves Mr. Richardson's hands he has no more control over the displacement of that vessel or the load line that he has fixed than I have, or anybody else who has never seen the vessel. Therefore, in the first place, I cannot admit that the displacement fixed by a builder is the proper, and scientific, and the best basis for scantlings. In the next place, Mr. Richardson says that he proceeds to find the thinnest plating which he can put on the ends of the vessel. That is the first practical step he takes towards arranging the scantlings of the vessel; and he arranges the end plating on the principle that a wave will hit a big ship harder than it will hit a little one. He tells us he is not sure whether a wave will strike a 4,000 ton ship twice as hard as a 2,000 ton ship; but he assumes that there is some relation between them, and he forms as he says a conventional scale; but what that conventional scale is he does not tell us, and we have no means of judging.

Mr. J. W. RICHARDSON: I said proportionate to the tonnage, or at least so I intended.

Mr. W. JOHN: Supposing it is, I do not think we should be right in assuming (and we have not the least ground for assuming) that the blow of the wave on a vessel is in proportion to the size of the vessel. It depends upon the relative size of the vessel and the wave I grant, but it varies greatly according to the size of the wave and presents a very involved problem. Therefore I think that basis is not a sound one to rely upon. Then the next step Mr. Richardson tells us, is to find the centre of gravity of the fore-body of his vessel, of the hull of his vessel, of the cargo, and of the engines and boilers. But Mr. Richardson has not yet found the scantlings of his vessel, and how then can he find the centre of gravity of the hull or fore-body of the ship? In the next place he says he finds the centre of gravity of the cargo, but he has no control over the stowage of the vessel, and he cannot therefore find the centre of gravity of the cargo. The same may be said also with regard to the engines and boilers. Here Mr. Richardson recommends manifest impossibilities. Then Mr. Richardson tells us that, having got the centre of

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gravity G, and multiplying the distance from A to G by the weight of the fore-body, he gets the strain the vessel would have to endure if she were suspended in the centre, and assumes that the greatest strain afloat would be one-third of that. I am not now disposed to question the closeness of that approximation. It agrees with the calculation which I had the honour of laying before you last year, although later on Mr. Richardson seems to think that his calculation and mine differ considerably, but you will find from my Paper that the strain afloat is about one-third of the strain when pivoted. Then having got this strain afloat how does Mr. Richardson adopt it. He tells us that he finds the strain on the upper flange of his girder, on the stringer, and shear-strake, and the iron deck if he has one, and proportions them accordingly without reference to the remaining scantlings.

Mr. RICHARDSON: And the side plating.

Mr. JOHN: No; I beg pardon. Mr. Richardson then says he fixes the side plating and the bottom according to a conventional scale? It seems to me—and I think you will agree with me—that there is far more convention than theory or science in any formula of this kind; because the only things that enter into the formula are those which comprise the upper flange of the girder, all the rest being left to a conventional scale, and whatever that may be we do not know, and Mr. Richardson does not tell us. Mr. Richardson says that there are three kinds of strains on vessels—the transverse strain, the longitudinal strain, and the side strain. How has he discussed the transverse strain? He does not tell us on what principle he fixes the size of any part of the framing of the vessel; but he says bulkheads are the principal means of transversely stiffening vessels; and he adds it is curious enough that sailing vessels, which have the greatest transverse strains, have no bulkheads, whilst steamers have. Mr. Richardson does not tell us that the section of sailing vessels is larger in proportion than in steamers, that the frames, as a rule, are larger, and the form of the sailing vessel is such as to afford much greater transverse strain; but while he is pretending to instruct the Register Societies as to the principle on which they should base their scantlings, he leaves us entirely in the dark as to how the transverse strength should be regulated. Now, Mr. Richardson next gave a formula, *viz.*, the displacement, multiplied by the length divided by twelve times the depth; and he tells us that will give the strain on the upper part of the girder. He compares this with the formula which I gave last year—an approximate formula for the bending moment, *viz.*, displacement multiplied by the length and divided by 35. He tells us that the strain he obtains is three times as great as that shown in my formula. It seems to me that Mr. Richardson has omitted to notice that he has the depth in the denominator of his fraction as well as the twelve, and that the formula which I gave was a bending moment, which has to be borne in certain proportions by the whole section of the vessel. Mr. Richardson's formula gives us something which I really cannot call a bending moment, but which is supposed to give a strain on the upper part of the vessel quite independently of the bottom plating and side plating, and every other part of the vessel. He seems to think that he has found out the strain on a vessel at sea to be three times as great as that which I gave, and he tells us to what he thinks the difference is due. He has kindly given us some diagrams to illustrate his views. The diagram, Fig. 19, represents the position of a vessel on the crest of a wave, balanced in equilibrium, the water having left the ends of the vessel, and the vessel is for the moment in statical equilibrium, so that you have the bending strain due to the fore-body equal to the bending strain due to the after-body. This is one of the principal cases I took. But he takes a vessel which shows more of her fore-body out of the water and the after-body immersed, and it is true he seems

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to have more overhang in the fore-body. Apparently he forgets the fact, that, while in the one case the bow and stern are both pulling down to break the vessel in the middle, in his case the weight of the bow is pulling down, and the buoyancy of the water is lifting the stern; so that, instead of bending the vessel, he is tilting her. It seems to me—as a matter of science, of statics or dynamics—you cannot assume that the fore part of the vessel is an overhanging weight to be dealt with statically in the same sense as you can in the middle drawing. The position which I assumed the vessel to be in was the position of the greatest strain; and I may say, in doing so, I was merely following what Mr. Reed and other shipbuilders and scientific men had assumed, with great reason, to be the position of the greatest strain. Let me give a popular illustration of this subject:—Take two boys, one on each end of a plank which is pivotted at the middle. You have the breaking strain of the plank equal to the weight of either boy multiplied by his distance from the fulcrum. Mr. Richardson says in effect no; put a little boy on one side and a big boy on the other side, and take the breaking strain of the plank as the weight of the big boy multiplied by the distance. When Mr. Richardson gets up here to lecture the Register Societies upon basing the scantlings of vessels on scientific principles, I really think he should be a little more careful to be sound in his own scientific deductions.

The CHAIRMAN (Mr. J. Scott Russell): I would ask whether you could not get a level balance with the big boy and the little boy by shifting the centre a little. The fulcrum, I beg to say, is shifted at the same time. You should take that into consideration.

Mr. JOHN: I quite agree with Mr. Scott Russell, but in this case the fulcrum is shifted in the wrong direction; or, even worse, as the overhanging weight is pulling down one side, and at the stern there is more buoyancy than weight, which tends to lift the stern, so that it is like one boy pulling down one end of the balance and the other boy lifting up on the other side.

The CHAIRMAN: I quite agree that it is rather a dynamical problem, in that case, than a statical one.

Mr. JOHN: Quite so. I think Mr. Richardson will have some difficulty in proving that the strain on a ship in such a position as he has taken would be three times the strain of a ship in the position of being balanced on the hollow crest, both ends lifting up or pulling down opposite to each other.

Mr. C. H. JORDAN: I feel that this is a subject which demands our best consideration, and I think there can be no doubt that we have had a very able Paper read to us by Mr. Richardson. It is, however, a subject into which I cannot freely enter, considering my position as a surveyor to one of the Register Societies. But I may say that I support Mr. Richardson to a very great extent in the view which he has taken with reference to the displacement of a vessel being used as a means for determining her scantlings, and I think it is a point which demands, and should receive, the most careful attention of the Committees of the two Register Societies. I certainly disagree with Mr. John's opinion upon that point, for I think the displacement should, to a great extent, enter into the formulæ for determining and regulating the scantlings.

Mr. CHARLES LAMPORT: Allow me to say that I think very great misapprehension exists with reference to the nature of the strain on a ship from the movements and influence of waves. We have heard a great deal to-night of the effect produced on ships from the impact of waves. But I think when

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Mr. Richardson used that phrase, he had a little overlooked the fact that as a wave travels along, its action and influence are always upright. The true representation of the influence of a wave at sea is precisely shown when you get a quantity of air under a carpet. You see when you shake a carpet that, the ripples run along, but you know very well that the surface is not changed. Everybody knows that at sea, although the waves have the appearance of running along the surface very speedily, and seem likely to strike great blows called impact, that anything floating upon them, is merely borne upwards and as the wave passes it drops down again in precisely the same position. The impact of a wave upon a structure like a ship must depend entirely on the results of the wind in catching the crest of the wave, and forcing it out of its ordinary position. That was the result of the observations I made during a voyage half round the world, and my feeling was that the ordinary waves had very little influence in straining the structure of a ship. When it comes to a question of a ship badly laden, and when, in nautical phrase, she is labouring much, particularly in the trough of the sea, it seems to me that the strain arises, in a great many instances, from the centre of gravity of the ship and cargo being placed too low. Therefore the ship labours considerably. Then again as regards a fixed load line, although Mr. Richardson in what he suggests leaves it optional, like Mr. Norwood, to the shipowner, I think that would only lead to a delusion. I would venture to state that one of the points which Mr. Plimsoll has got hold of as to overloading ships, and one of the delusions which he is under as to the unseaworthiness of ships, is owing to a very unsuspected cause, namely, that of late years the application of hydraulic pressure to the cargoes of ships and Manchester goods of various descriptions has been such, that although when I was a young man and engaged in the Manchester trade, these goods were 40 feet to the nominal ton, now the goods regarded as measurement goods are in reality dead weight. The result of this is, that the shipowner cannot fill his ship with an ordinary outward cargo because it is too heavy, and unless he gets, say, a lot of hat-boxes, or something which can be regarded as real measurement cargo and not dead weight, he has not the power to make a fair-paying and easy cargo for his vessel. Of course he cannot complain of this—he should build his ship to carry the average of cargoes—but I think that this consideration ought in some respects to be taken into account. That kind of export cargo has of late years been much increasing, and I venture to say that cases and bales of bleached calicoes, and of Manchester goods, subjected to great hydraulic pressure are in reality not measurement goods as taken and paid for, but actually dead weight. Mr. Richardson spoke about the effect of bulkheads in resisting the transverse strain, by which I suppose he means the strain of torsion—resisting the tendency of the ship to twist.

Mr. Richardson: No, not quite so.

Mr. C. Lamport: The transverse strain at sea would have little effect beyond that. At all events there is a strain of torsion upon the ship. I venture to say that a ship with only a few bulkheads in her is subject to a dangerous strain from the position and mode of fastening those bulkheads. I know a ship while crossing the Bay of Biscay leaked so much that she had to put back, and when she was placed in a dry dock in Liverpool every rivet in her foremost bulkhead had broken, and if the whole of them had happened to have come out, as a number of them did, it is very doubtful whether that ship could possibly have been saved. And why? Every one of these bulkheads is fixed and inflexible, but in a structure which is, and always must be, when made of iron, to a certain extent flexible, if you make certain rigid points and attach them with rivets which are weaker than the plates they are attached to,

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when you twist that ship and subject her to a transverse strain you are very liable to injure her structure. Therefore, when people talk of bulkheads as an unmixed good, I often smile and think that they really are creating a means of unsuspected danger. Now I only want to say one word with regard to the proportion of stringers fore-and-aft. I think Mr. Richardson has entirely overlooked the fact that the strain upon a ship is not entirely due to the shifting position of the water-borne portions. The foremost part of the ship and the deck have to resist the strains arising from the cable of a ship while she is at anchor, and to resist strains in the foremost part of the ship which may not be water-borne. With regard to the after end of the ship, there is the vibratory action of the propeller which is very destructive as it seems to me; and if the stringers and all the proportionate parts are not strong enough to meet these strains, but are fined off with a view entirely of meeting the strains brought to bear upon her by the sea, the ship will ultimately suffer.

The CHAIRMAN: Allow me just to call your attention to the diagram (Fig. No. 5). You will see there by the proportion of the ordinates to each other that the difference is not so great as you think at present.

Mr. C. LAMPORT: That has sole reference to the displacement, but I wanted to show that there are other considerations besides the displacement, which act exclusively fore-and-aft of the ship. I want to call the attention of the Meeting to the fact that looking at Fig. 2, it would very seldom happen that a ship would be in such a position. I mean to say that if you took a dead sea level you could not get the ship lifted up bodily by the influence of a wave as represented in Fig. 2. If the ship is lifted up, the strain, I venture to say, upon the structure of a ship is not represented by the unsupported ends, as shown. I put it in this way. Suppose you take a small ship out and throw it up in the air. While it is up in the air, the force which lifted the ship also suspends the action of gravitation on a ship for a time, and the whole of the ship while in the air, and until she comes down, has no more differential strain on it than there would be if she were water-borne.

The CHAIRMAN: You say it is sent up by impulse and gradually comes down again; and at that critical moment you think you cannot say there is a great strain upon her.

Mr. C. LAMPORT: It is the same as a nurse would take a fragile tender infant, and without doing it any injury, would throw it up in the air and receive it gently down again.

Mr. MARTELL: Perhaps I may be allowed to offer a few remarks since I, together with Mr. John, represent one of the Register Societies criticised by Mr. Richardson. I certainly was surprised to hear Mr. Richardson state, as a practical man, that it would be wise, instead of extending stringers fore-and-aft, to fine them away or to leave them out altogether at the ends of the ship. Now, irrespective of any theory, such a practice would be contrary to all experience. There are many shipowners here. I see around me the owners of iron ships, and they know as well as I do that the ends of ships, particularly sailing ships, require a considerable amount of rigidity. You can obtain this rigidity from the plating to a very small extent only; and it has been said by some that plating and stringers have been too much reduced already at the ends by classification societies. I could name to you ships that have arrived in India when a considerable amount of cargo has been found damaged, owing to panting of the ship forward caused by plunging into head seas; and the consequence has been that the beams have been torn away. I have seen instances where ships have come into port with their hold beams forward merely

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suspended on the battens, and all the rivets were sheared off entirely by this panting, showing that you require even more rigidity than is sometimes supplied, and that the stringers must be carried right fore-and-aft, and connected at the ends with hooks and crutches. There was a vessel in dock in London a few days ago, in which this weakness at the ends was apparent. There were two beams fitted forward for the purpose of giving rigidity at the part near the foremost bulkhead; and from this panting motion the whole of the rivets were torn out, and the ship leaked at that part. I see gentlemen here who have seen the same thing with their own ships; and it is remarkable to see Mr. Richardson bringing forward a recommendation on scientific grounds, which is altogether contrary to the experience of practical men in the habit of seeing ships as they come home after performing their voyages. It might suit builders who build ships on supposed scientific principles, and who never see them after they come back again; but we who see them when they come home see the effects of such science, and we have to be extremely guarded in embodying such principles in our Rules. To tell us that, instead of having a complete iron deck, if you took away the middle line portion you would make a stronger ship in any direction, seems to me to be a perfect absurdity. Many strained ships have come under our observation; and we have had to recommend what was necessary to make them seaworthy, and we have found that where ships have had partial iron decks, plates connected at the sides of the stringers, but not connected athwart-ships across the middle line, the ships had worked and strained, and had caused the decks to spew out the oakum, to use a technical expression, and the water has got in and damaged the cargo. The deck has been taken up, the iron deck completed so as to connect both sides of the ship, and the ship has gone away and done her work well. I think one single fact of that kind gained by experience is worth a whole lecture on science; and I consider that it is a fact practically proved and positively seen. Now, what do we too often find amongst shipbuilders who want to deviate from the rules laid down by Register Societies? In the first place I have always found, and no doubt many here can corroborate me, that the great aim is to save materials. Have they all sufficient scientific knowledge, are they willing to put themselves to the necessary trouble and expense of adopting a new system of construction such as our Chairman has introduced? We find commonly that they take our ordinary principle of construction, and simply reduce all the scantlings till they get down to sizes they know nothing about, and have had no experience of. They are not governed by any large experience, and are only too likely to produce a vessel like the steamer *Mary*, which goes out, and without much warning, breaks bodily in half. Mr. Richardson knows as well as I do (and he can corroborate me) that there is a practice known in the trade, when a builder has a ship to build and it is left to him as to the classification, for his draughtsman to get out in minute detail the weights that will enable the ship to be classed in Lloyd's, or the Liverpool Registry, or the Bureau Veritas, and see which it is most profitable to build. He adopts that classification where there is the least iron compared to the price he can secure. This has been the case formerly more than at present, and I can prove it as a fact; but owners now for the most part decide the class for themselves. This leads me to an important element in a Register Society, which is, to guarantee to the shipowner that he gets what he contracts for. The Admiralty in building their ships are compelled, for certain reasons, to restrict themselves to a particular draught of water. They give rigid orders to their surveyors to keep down the weights, and they allow the contractor to go five per cent. below contract specification; and the consequence is that many builders of merchant ships order their iron plates and angles five per cent. below the specified size—that is to say, they will order so many square feet of half-inch plates 20 pounds to the superficial foot, less five per cent. The surveyors to our Society have the

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greatest difficulty in seeing that the scantlings are kept up to the required sizes on account of this. I say that that is a great element of usefulness of the Society to a shipowner, because it enables him to know that he gets the quantity of iron he pays for, and if it is only a 32nd of an inch under, even that is not allowed to pass. By that means the shipowner gets the exact scantlings he contracts with his builder to supply. I wished to make these few remarks in reply to Mr. Richardson.

Mr. RUNDELL: I have now come to an age when I can indulge in a little retrospect as well as a little prospect; and my observations on this subject will be divided in this way. First, the retrospective part. No doubt some part of this Discussion will remind you of the celebrated paper war which took place between Dr. Scoresby and the present Sir George Airy as to the impact of sea waves. That eminent mathematician described the impact of waves as a washy influence. On the other hand the sailor, Dr. Scoresby, who had been many times to sea and met with waves, knew it was something more than this; and I think if he had been here he would have told us what Mr. Richardson has also told us, that the impact of a wave on a large and a small vessel are really two different things. It varies with the inertia of the vessel: in one case the whole mass may be moved, in another a portion of the structure may be broken instead. So much for the retrospect, and now for the prospect. I think we can, if we try to do so, see the tendency of current events and what they are leading to—not exactly prophetically, but according to probabilities. Now, the probability to which I am about to allude is a change in the mode of classification. If we go back to the year 1834, when Lloyd's Register was first formed, the book that immediately preceded Lloyd's Register gave the load draught of ships for the information of underwriters. The Foreign Registers now generally do the same. It is essential to the underwriter to know how deep a ship ought to be laden, because it forms part of the risk which he is taking. Now something of the same sort seems to be coming again. A vessel's strength will be estimated by the proportion she can carry of her total displacement. We shall have Registers by-and-bye, not indicating character by 100 A or 90 A or 80 A; but by load draughts, and saying that such and such a vessel shall have 30 per cent., another 31 per cent., another 32 per cent., and another 33 per cent.; so that really the registration or class will be the percentage of buoyancy that is to be left on the vessel when loaded. I think that is what we are tending to. There is one other remark which I wish to make. I think Mr. Merrifield could very easily tell us as to the possibility of Sketch No. 21. I think he would tell us that such a vessel's bow would fall at a maximum rate of perhaps 16 feet per second for the small space it had to fall: of course if it fell for one second, at the end of that second it would have a velocity of 32 feet. For the wave to pass such a vessel at the rate shown there, he would tell us that the wave must be of a certain size, and of a form which would make it an impossible diagram. The conditions of gravity and the conditions of wave motion make it rather improbable.

The CHAIRMAN: I think I have seen a boat in that position, and I am afraid I have even been in one.

Mr. LAMPORT: I have been in a 1,000-ton steamer and sat in the bow and seen her fore-foot.

Mr. RUNDELL: I do not doubt it at all; but the length of the vessel and the length of the wave could not be in these proportions. Now, one other remark as regards Figure 5. I think that is an excellent diagram. I am not going to defend the curve. It may be a parabolic curve, but I can see that a curve of sines would suit very well. Let me give a description of it in this way. Let O B at the end be the minimum thickness of the plate that you could afford to have either for wear and tear, or

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for any other consideration that may come into play. I draw a line parallel to the bottom line through O to meet A P in O′. A P will of course represent the thickness of the plating amidships = O B + O′ P. Represent O′ P by p, and the other vertical lines above the line O′ O by p_1, p_2, p_3, p_4, p_5, then the thickness of the plating for these positions will be respectively O B + p sin. 75°, O B + p sin. 60°, O B + p sin. 45°, O B + p sin. 30° and O B + p sin. 15°. There you have it exactly, and it really shows there is something like a scientific basis for that diagram. I am certainly not going to upbraid Mr. Richardson for having come so far to ventilate his views, because I am sure that none of us can have listened to what he has said without having received a great deal of information and instruction; and although we may not agree with the whole of his Paper, there is much in it worthy of consideration.

The CHAIRMAN: I am afraid that however valuable this Paper is, our Meeting must speedily come to a close, and therefore, I shall say nothing except this, that it has given me very great pleasure indeed to-night to hear a gentleman of so much practical experience give us his best views of the mode in which he, a practical man, has been in the habit of building and calculating ships; and as we know that a great many of those ships are very good ships, let us hope that that is some testimony to the accuracy of his calculations. Now, Gentlemen, I find in this world that a great many of us agree much better in our conclusions than we agree in the ways of arriving at them; and my impression is that the opposite sides in this controversy agree upon a great many points that they have not mentioned, and have only given us the points on which they differ. Now I am sure you will agree entirely in this—that as a general rule, especially in a long ship, there should be a great increase of scantling in the middle of the ship; and that necessarily involves a very considerable diminution in the other parts of the ship. Then observe, I agree entirely that there are parts of a ship which are sometimes left foolishly weak, and I agree especially that in the stern of a ship I have been compelled, I confess, enormously to increase the scantlings of the skin and other metal in the *arrière* of the ship beyond all my wishes and reasons and calculations, on account of the great multitude of local strains which come upon the stern of a ship from her propeller. And on the contrary there is a great chance of making the bow of a ship—in fining it—much too thin; because, while other parts of the ship are generally round, that portion of a ship is generally a dead flat, and therefore it requires a treatment totally different from the other parts of the ship. I think, however, that the writer of the Paper is just as likely as we are to strengthen his ship at the stern on account of the propeller, and to strengthen the bow on account of its flatness, notwithstanding his theory that a parabolic line represents really and approximately the diminution in the general strength of the ship. I also entirely agree with the last speaker, that, if you like to interpret that parabolic line as a curve of sines, or as a wave line, it will answer the purpose just as well whether you call it a curve of sines or a wave line. I will now ask Mr. Richardson to reply as shortly as he can to the vigorous and decided attack which has been made upon him.

Mr. RICHARDSON: With regard to Mr. John's remarks, I can only say that throughout he seems to have simply misunderstood me. I have given the calculations in detail in my Paper, and he can check them if he think fit; and the public have generally had so much regard for Mr. John's reputation as a mathematician that his opinion will be sure to carry great weight. I was puzzled to understand the difference between us, and this sketch I made was a suggestion of the difference; and if I am wrong in taking that extreme case; my calculations must be reduced to that extent. As to the illustration of the two boys balancing themselves on a plank, that is not worthy of observation. That is a thing so

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elementary that I do not take any notice of it. I do not think that Mr. Martell is quite candid in the observations he made. I was very careful in all my remarks to say that, as regards longitudinal strength, you must be careful to provide strength for the vibration of the screw propeller, and the local strains, and the impact of waves; and Mr. Martell knows very well that in our establishment we have built too many ships not to know that that is necessary. This is the main question—if you are designing a ship, and if you are establishing, by a very influential Society, a hard and fast rule for the scantlings, on what basis is that to be put? Supposing you are making a vessel to bear some internal pressure—to use an extreme illustration, if you make it in the form of globe you would have the largest capacity and the greatest strength, with the least material and perfect form; but if you were to make that vessel a cube instead of a globe you would have a greater strain on the surface. But if the Rules state that because the outside dimensions of the skin are greater than the outside dimensions of the cube therefore your strength must be greater, what a *reductio ad absurdam* do we get to? Lloyd's Rules bear hardly upon us in this respect, and I believe I am doing a kindness, and acting in no spirit of criticism on Mr. John's Paper, in trying to give them the support of the public in saying that the strength of a ship should be in proportion to the strains on a ship.

The CHAIRMAN: I will only take the liberty of adding one word. I would ask those gentlemen who have spoken to-night on this subject seriously to consider whether after all the girth at midships is not the great element by which to calculate the strength of a ship?

Mr. MARTELL: That is the basis of Lloyd's Rules at this time.

The CHAIRMAN: I am very glad to hear it.

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ON THE "BESSEMER" STEAM SHIP.*

By E. J. Reed, Esq., C.B., M.P., Vice-President.

[Read at the Sixteenth Session of the Institution of Naval Architects, 20th March, 1875; the Right Hon. Lord Hampton, G.C.B., D.C.L., President, in the Chair.]

My Lord and Gentlemen,—I am extremely obliged to the Meeting for accepting the arrangement with regard to my stating extemporarily what I had intended to have embodied in a Paper. I fully intended to have read a Paper upon the present occasion; but, for the reason which your Lordship has stated, I have been unable to find time to prepare it.

The *Bessemer* steam ship was designed for a special purpose, as is pretty well known, and the designing of her involved some very interesting and novel problems in shipbuilding; the chief of which is the object for which the vessel was designed, *viz.*, to support a saloon which was to be made unsusceptible to transverse oscillation, by the application to it of machinery. I may say that Mr. Bessemer's idea was, and is, to apply his machinery not only to the transverse motion of the saloon or cabin, but also to the longitudinal oscillation. But, as this vessel was intended only for Channel service, and as it was to be a large vessel, performing the service in comparatively small waves, it was thought desirable by Mr. Bessemer, as well as by his friends, that he should limit the first application of his system to the correction of transverse oscillation; and, therefore, the problem was, in this case, to design a vessel which should have a very light draught of water for so large a ship, which should be double-ended, so as to go in and out of the narrow harbours of the Continent without the necessity of turning round; which should be fast; and which should, at the same time, have in the centre of her a space about 86 feet long, which would be entirely free from everything but the *Bessemer* saloon and its appliances. The first effect of this was to drive the machinery of the ship—which in high-powered vessels, at any rate, is usually near the centre of the vessel—quite away from the centre, so that the engines or boilers could not be

* Received 20th March, 1875.

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placed within 43 feet of the midship-section of the vessel. This necessity raised the question as to what would be the best application of propulsive power.

It will be obvious to this Meeting that it was quite out of the question to consider that either one or two screws, in a vessel capable of entering the shallow harbours of the Continent, would be able to deliver sufficient steam power to drive her at the large speed required—which speed, I may state, was to be fully equal, at least, to that of any of the vessels now performing the service—the idea of Mr. Bessemer and his coadjutors being that she should be somewhat faster, certainly not slower, than any of the existing vessels. We naturally were driven to the consideration of the application of the steam power to two paddle-wheels, and from two sets of engines, instead of one; and there was the responsibility of saying whether this arrangement, carried out as shown in Plate I., in which the paddle-wheels are placed more than 100 feet apart, would be effectual. And I must say, that the general impression—and the very general impression—was, that it would not be successful, and that the second engine and its paddle-wheels would be of comparatively little value; but I doubt whether that opinion was ever shared in by the thoughtful Members of this Institution. If you suppose that the whole of the revolutions of a paddle engine, when a ship is going at an enormously high speed, are employed in producing that speed, from moment to moment, it is very natural that you should draw the inference to which I have referred; but, when you think for a moment, you will see that an ordinary fast paddle steamer, with her engines making probably 35 revolutions, and going at some 15 or 16 knots, really has those engines making over 30 revolutions for the one single object of keeping up with the vessel, rather than propelling her: by which I mean, that if you were suddenly to remove the engine-power and the paddle-wheels, the ship would still go for a certain short period of time at nearly the continuous speed which it was maintaining without the application of any power at all. What the engine does from moment to moment is to prevent the degradation of speed, and to keep it up to a uniform amount. It is the few last turns of the wheel which do the propulsive part, by far the larger number of turns being required for the purpose of keeping the wheel at the pace of the vessel without exerting any propelling effect at all; because if the wheel went slower than the vessel it is obvious that it would be a resistance to her progress, and to avoid that you are obliged to turn the wheels at a considerable velocity: the additional revolutions made to keep up the speed are very few. And therefore I thought if you placed a second wheel at some distance from the first, the disadvantage it would be under would not be great, chiefly having relation to those last few revolutions, and not to all the early number of revolutions required for merely keeping up with the ship; and I went so far as to predict with some confidence that there would not in fact be found a greater

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difference in the revolutions of the two sets of engines, when both were performing equally efficient services, than about four or five. Of course I quite admit that there was some speculation in that view, but that was the conclusion to which, after much consideration, I, for one, came.

Perhaps this is the moment to say, my Lord, that we have had the ship out three times on considerable runs, and when both engines were doing their best the difference between the revolutions of the engines did not exceed two. The after engine certainly exerts its power, and therefore it must deliver its power with only two revolutions more than the foremost wheel. I might mention that I believe this arrangement of paddle-wheels is not entirely new, but I think it has been adopted on former occasions in light-draught steamers. I cannot advert to particular instances, but I well remember my friend Mr. Penn, the eminent marine engineer, once telling me he was about making double engines of that kind for the purpose of propelling light-draught vessels on some of the American rivers.

Mr. John Scott Russell: And on the Danube.

Mr. E. J. Reed: Yes, and on the Danube. The consequence is, as far as this point goes, it is not very novel, except to us, but it certainly was novel to me at the time. I am glad to say that the *Bessemer* has, in my opinion, established the fact that when the necessity arises you can apply the propulsive force in two parts by two totally independent engines with separate paddle-wheels. Of course the further question remains how near together you could bring those wheels without great loss, and upon that point it is impossible to speak with confidence. All I can say is that if you look at the water between the first and second wheels as the *Bessemer* is going at high speed, although there is a good deal of boil and motion, it does seem to be certainly approximately at rest and to oppose the revolutions of the second engine, which is what you want. I think that all doubts as to the efficiency of the arrangement will disappear from every practical mind when they once see the ship in operation, and witness the relative velocities of the two wheels and the state of the water.

Mr. J. Scott Russell: How far apart could they be got?

Mr. E. J. Reed: The wheels of the *Bessemer* are somewhat over 100 feet.

Mr. J. Scott Russell: Could they go farther with advantage or disadvantage?

Mr. E. J. Reed: They were placed where they are simply by the consideration that we had to leave a certain length in the centre of the vessel for Mr. Bessemer. The object of leaving that length was to enable Mr. Bessemer to plant his saloon in that part of the vessel which was subject to the least oscillation in a longitudinal sense; and

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I must say, when the *Bessemer* saloon was quite at rest, and the machinery of it was not in action, and when the ship was in a considerable sea which we experienced, the small extent to which you then felt the pitching motion of the ship was very slight indeed; but that is largely due to the fact that the ship herself does not pitch much.

This brings me to another point, which I will mention here because it is peculiar to Mr. Bessemer. It was adopted in the ship by his wish, and represents a view of his own, and that is the adoption of the low ends as shown in Plate I. Mr. Bessemer, having consented to forego the attempt to control the cabin by power, both in its longitudinal and transverse oscillations, was naturally desirous of reducing the pitching motion as much as possible. I doubt whether he was so desirous of reducing the rolling motion; for I think that Mr. Bessemer's saloon and appliances would have exhibited themselves with much greater advantage in a badly-rolling ship; because it is perhaps easier by his appliances to take a large roll out of a vessel, than to follow all the delicate movements of a vessel that rolls but little. But in a longitudinal sense he was most anxious to have the ship very steady, and his idea was that if you made the ends low, so that as soon as she got into any kind of sea it would roll over them, the causes which induce ships to rise and fall and pitch would be eliminated to a large degree. I must say that I, for one, do not like these low ends for ships. I do not like them because they are bad things from a sailor's point of view. It is extremely unpleasant to have all your capstans, and anchors and cables where they are so much out of reach; and naturally the objection may be taken that at the time when you most want to use your anchors and cables—in a gale of wind—you will have great difficulty in doing so. Even in the case of the *Bessemer* herself—which is far too large a vessel to enter the inner harbour at Dover, where other vessels retreat, when there is bad weather, until it has passed over—it would be necessary for her to use her anchors and cables, and no doubt there will be at times some inconvenience in that respect. I need hardly say that we have taken the greatest pains to get rid of those difficulties, and the capstans are fitted with hydraulic power, and all the arrangements are as simple as they could be made. At the same time it is proper to say, that whatever differences of opinion may exist, from a sailor's point of view, as to the character of those low ends, that in this ship, in co-operation with other causes possibly, they certainly are most successful in producing longitudinal steadiness. For my part, I never expected to live to see a ship of the size of this one perform, in heavy seas, as I have seen the *Bessemer* perform on the voyage from the Humber to the Thames.

Upon the morning of the day that succeeded the night of our departure we still had a very heavy sea, and many ships passed us—modern steamers—with that peculiar combination of pitching and rolling, and rising and falling, which is so very unpleasant

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even to look at. I may say that the sea was rough enough to induce large vessels to lift their fore-feet quite out of the water, and to plunge their forecastles under water; but at that moment the pitching motion of the *Bessemer* was almost *nil*. When you stood upon the end of the upper deck and looked down on the low part, it is fair to say it was as often out of sight as in sight, the sea completely covered it, and all the inducements for the ship to rise and fall seemed to have disappeared, or nearly all. I should not like to exaggerate this. You will yourselves have an opportunity of judging whether there is any exaggeration in what I say, but my impression on that trip was quite borne out by other persons on board. The pitching of the saloon was of the slightest possible kind, and, therefore, that is particularly satisfactory with regard to this vessel. I may say that we were dealing on that occasion with seas of a class for which this vessel was not intended, and I should not have been at all surprised to find the *Bessemer* knock about with considerable violence (as she is a comparatively light-draught ship for her size) poised in the surface water of such great waves.

Perhaps in this connection I ought to mention the rolling, and dispose of that before I speak of other points. A ship, as naval architects know, will design herself when you have certain things given; and in this case there was very little scope for the designer to carry out his plans in such a manner as to greatly interfere with or modify the rolling motion; and, therefore, having given as much attention to that head as I could give, considering the plans of the vessel, I turned to the discoveries of my friend Mr. Froude with reference to bilge keels, and the facts he has developed; and I thought it desirable to give this vessel at any rate bilge keels of considerable depth, and the *Bessemer* has bilge keels of 2 feet 6 inches in depth and of considerable length. They are low down (*see* Plate II.), and are put so as to interfere, or be interfered with, as little as possible by the paddle-wheels, but they run throughout the space between the paddle-wheels. It must have been obvious to every person on board that the rolling of that vessel is largely modified and reduced by the existence of those bilge keels. She does not roll with that uniformity of motion from side to side which is common in ships at sea. When she is obliged to roll from the action of a wave, or a succession of waves, you can almost immediately feel that the bilge keels are taking the roll out of her, and you see her almost within two or three oscillations of a considerable roll, quite steadying herself, and occasionally, in the midst of great waves which are rolling other ships systematically, you will see her steadying herself in a remarkable degree. I think it unnecessary to dwell any more on this point, because the nature of it is understood by the Institution.

It will be seen that this vessel, from the peculiar conformation which I have described at the ends, has introduced this question of a structural nature, namely, What

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is to be the top of the ship in which we are to place our strength? There was no doubt about the bottom of the ship. That is a very broad flat girder, and we only thought it necessary to reinforce the natural strength of the bottom by doubling the flat keel plate, which is unusual in merchant vessels as you know, and building the ship with her chief strength in a longitudinal direction. There are three longitudinals, as will be seen from Plate II., on each side, and so far there is no question about the strength of the bottom of the vessel. But it was a serious question how to deal with the top of the girder. What has been done is this. In passing from the upper deck to the low ends, we have adopted a somewhat novel device, because we have continued the stringer and outer sheer strake down in the form of a great angle iron or half girder as shown in Plate III. We brought it down and allowed both the stringer and the sheer strake to lose themselves in the plating of the side and the deck, curving the side in the lower part. The details of the arrangement are shown in Plate III. At section F the upper-deck stringer plate begins to slope in such a manner that it just clears the lower side of the upper-deck beams at section E, or in other words it does not interrupt the regular succession of the beams. The stringer plate slopes in this way, but without any twist for about 18 feet from F, where its outer edge commences to cut through the side plating of the breastwork, and is rounded down gradually more and more until at section A it conforms for its whole width with the round of the sides of the low ends. The angle iron on the lower edge of the upper-deck stringer is sloped down with the plate, but does not cut through the side plating of the breastwork with the stringer. It is run on to meet the lower-deck stringer at the inside of the frames of the breastwork, and it is then turned back to meet and be strapped to the continuous angle irons of the lower-deck stringer. The angle iron on the upper side of the stringer is also sloped down with the plate; it does not cut through the side plating of the breastwork, but is simply carried on to meet and be riveted to the plating on the lower deck. The angle iron connecting the side plating of the breastwork to the lower deck outside, is worked up the slope of the stringer far enough to form a scarph about 8 feet long, with the angle iron inside on the upper edge of the stringer. The sloping part of the stringer plate is further supported, at intervals of 4 feet, by athwartship plates, worked the whole width of the stringer plate. These supporting plates are connected to the stringer by short pieces of angle iron, and are lapped on and riveted to the frames and upper-deck beams. Stiffening and supporting angle irons are also worked to the lower side of the stringer, immediately under the plates, where practicable, and as shown in section D. The doubling plate on the sheer strake is worked with its upper edge to follow the slope of the stringer, and where the outer edge of the stringer cuts through the side and is rounded down, the doubling plate is fitted over and riveted to the stringer in such a manner that no part of the stringer is visible from the outside of

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the ship. In point of fact, the doubling plate of the sheer strake is gradually worked so as to become a doubling plate to the sloping stringer. The sheer strake itself is continued round the end of the breastwork at the same height as it is amidships or at the upper deck. I think it will be seen that by treating the upper-deck stringer and sheer strakes at the top of the girder, and by bringing down the outer sheer strake and stringer to lay hold of the low ends in the manner just described, we contribute all that it is possible to do towards the support of this part of the vessel, both as regards its tendency to fall and to rise, this being formed so as to act as a strut as well as to give tensile strength to the arrangement. Great pains were taken in developing that plan to the fullest extent, and I believe it has resulted satisfactorily. But that is only how the top of the girder is connected between the two decks. The strength that we depend upon for the top of the girder we gain in the usual way by putting a very broad and strong stringer plate 6 feet wide. We have taken great pains to support it by partial bulkheads and partial beams, and everything has been done to enable that to act efficiently both in tension and in compression. I am inclined to think that by this arrangement the *Bessemer* is unusually strong, instead of being as she might have been, by the neglect of those considerations, very weak.

Then, the next point I will mention, in order to finish the structural observations, is, that the framing is similarly arranged to that of the *Inconstant* and some other vessels. There are deep frames, 6 feet apart, and shallow frames, made of a couple of angle irons, at intervals of 2 feet. In the wake of the engines the deep frames are 4 feet apart, and then we have one of these shallow frames between successive floors. In the other parts of the vessel, where the deep frames are 6 feet apart, we have two of these shallow frames between; so that, in point of fact, she has a frame at every 2 feet. Having deep frames at somewhat greater distances, with the intermediate supports of these shallow frames, seems to me a better means of getting the proper tranverse strength for the hull, with the least weight of material, than by having all the frames alike, as usual. In addition to these frames in the wake of the saloon, which is a long space, as you will observe, with nothing going across at all, it was necessary to give great support to that part of the vessel; and that we accomplished in this way—first of all, we took care to bulkhead the ship well at both ends; and then, as I said, we took great care to stiffen the stringers; in the third place, we put in plenty of these stiffening partial bulkheads; and, in the last place, we plated her inside; so as to form the side of the vessel into, as it were, a double girder on each side. Of course, it was a difficult and an unpleasant thing, from a naval architect's point of view, to leave a hole in the upper deck of your ship, 70 feet long, and within 14 or 15 feet of the whole width of your ship; but, certainly, I considered that there was nothing in the problem that could

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not be encountered, and I believe the strength of the ship, structurally, is perfectly satisfactory. It has received the full approval of Lloyd's Surveyors and all the professional men who have inspected it.

The only thing remaining to be said with regard to the structure, is that there are eight bulkheads in the vessel. It was essential, as I have stated, that this vessel should be double-ended—both ends alike—that both ends should be bows, and that both ends should be sterns, and it was necessary to have a rudder at each end. Many Members of this Institution know how much trouble has been given by bow rudders in double-ended vessels. I am strongly of opinion that most of those troubles have arisen from persons taking the rudder, as it were, out of the ship; by which I mean, supposing that [*illustrating*] to be the bow of the vessel, they have too often, as I think, treated that piece of her as a rudder, and made the rudder surfaces to conform to the water-lines of the vessel. If that is done, it is perfectly obvious that the ship must have a good deal of helm given to her before the rudder comes into play at all as a steering instrument. In the *Bessemer* we decided not to have that arrangement, but the one which I will now state to you. First, to end the water-lines of the ship proper at the rudder spindle, and treat the rudder just as an ordinary rudder running beyond it, and then to put a stem or stern-post outside that. The water-lines below all end at this point, and the rudder is nearly a plane. Above that it was of course necessary to have some increase of space to allow the tiller to work; and, therefore, the upper lines are of a fuller kind, so that in point of fact, the lower water-lines of the ship all end at the rudder-post as a stem, and the upper lines terminate at the ends of the vessel, and the result is that the rudder is nearly a plane of the usual kind. The ship was intended to be of light draught. Her intended draught was to be something less than 8 feet. Naturally, therefore, it was necessary to give great longitudinal surface to the rudders, and that has been done, of course in order to get the surface requisite for steering such a vessel.

I must say the only anxiety or doubt I have ever had about the performance of such a vessel has been with reference to her steering, because, the vessel being of such light draught, it must of necessity happen, or one would suppose it might happen, that in a very heavy sea the rudder would be frequently out of the water. I gave very serious consideration to that question in the first instance. I considered whether we should not introduce a second rudder going down into deeper water when the vessel was not in shallow water; but after making many calculations, and much considering the subject, I came to the conclusion that the simpler course was the best course, and that what we should do would be to make the rudder as I have described, and to give it an enormously strong spindle and rudder-head, and provide abundant steering power, so that when the rudder was struck by the sea, after being abandoned by the wave, there

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should be ample strength to resist all such blows. I thought if that were the case, the occasional abandonment of it would not result in any practical disadvantage, and up to this time there has been no indication of the kind. As far as I can judge, the *Bessemer* seems to steer extremely well.

I may mention that the whole of the steering gear and capstan work, and many other things in the ship, are done by hydraulic power, which has been supplied as far as the ship's fittings are concerned, by Messrs. Brown, of Edinburgh; and the facility with which this large vessel is steered by a small tiller which requires hardly any force to move it, is very admirable and also very remarkable.* The question then arose with reference to this steering arrangement, whether it was necessary to treat the ship in all respects as a double-bow and double-stern vessel? We decided on making some exceptions to that. For instance, we decided on not fitting spare steering appliances to both rudders. We thought that no circumstances could arise in which in the event of an accident to one rudder the other end could not be used as a bow, and we were not desirous to encumber the vessel with unnecessary elements.

I shall be expected to mention something about the speed of the ship, and I can hardly do that without referring to the weight of the vessel and the draught of water. As I have stated, all our calculations were based upon the assumption that the ship would draw something between 7 feet 6 inches and 8 feet. There are, however, many novel things in this vessel and in connection with Mr. Bessemer's machinery, and the desire has been to make it so ample and commanding and efficient in every way that a great deal of unforeseen weight has crept in in various ways.

Just for the interest of the Meeting, and by way of illustration of the manner in which it has crept in, and in order to show you that it was for the most part due to the precautions of Mr. Bessemer and the exercise of that fertile genius which he is known to possess, I may mention that instead of locking the saloon, in the event of the necessity of locking it arising, by some simple arrangement of blocks or ropes, Mr. Bessemer has introduced an extremely beautiful set of machinery, which lays hold of a dependent lever from the bottom of the frame, and in the sweetest manner possible is to force the saloon back into the upright position and lock it there with hydraulic power. It is a very

* Since the above was written the *Bessemer* has twice injured Calais Pier, owing to what has been called "not answering "her helm." Careful and repeated experiments made with her subsequently have shown, however, that the hydraulic steering gear does not allow the rudder to fly back amidships promptly, but requires nearly a third of a minute to put the helm amidships from the "hard over" position. In my opinion, therefore, the ship *was* "answering her helm" when she ran into the pier, due allowance not having been made for the time which the hydraulic gear required for centering the rudder. This is a serious drawback to hydraulic steering gear.—E. J. R.

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beautiful contrivance, and very efficient. I need not say that it involves more weight than the lashing the saloon with a rope or fastening it with blocks.

Then, again, the proprietors of the *Bessemer* ship have thought it desirable to work a great deal more of the fittings by hydraulic power than was originally contemplated, in order to add to the ship's efficiency. Among other things large hydraulic cranes have been introduced, and in this, and owing to some excessive weight in the engines, and possibly a very slight excess in the ship, there has been an accumulation of weight which causes a draught of 8 feet 6 inches, which is about the draught of the vessel at present. I mention this because it affects the question of speed, as the Meeting will see, in three ways. In the first place, all the extra immersion is the immersion of the bluff upper portion, and, therefore, the resistance of the vessel is increased in a much larger proportion than is due to the mere depth, because if it was the immersion of the finer lines below, it would not have mattered so much. In the next place, the centres of the paddle-wheels are lowered in some degree, and this makes the engines work at some disadvantage with regard to the angle of the impingement of the float on the water. It has also rendered necessary some reduction in the paddle-floats.

I mention these things, frankly, because there is nothing in this vessel that needs any kind of concealment; in fact, the object has been, throughout, to get the public interest excited in the vessel, and to cause them to know as much as possible about her. They will certainly affect the speed; but I may say that, anticipating in a large and novel undertaking of this kind—in which several persons were to be interested in addition to the designer of the vessel, where his control would be limited—there would be some alterations, we took the precaution of increasing our displacement in the laying off, allowing some margin, or I am afraid she would have been still deeper. We also took the precaution—which was a proper one, and is a satisfactory one at present—of putting power enough to have driven her, at her original draught, I believe, over 20 miles an hour. Therefore, we have high speed, to have something taken from. I cannot quite say, from the causes I have mentioned, exactly what speed we should anticipate—especially as up to the present time, owing to various causes, chiefly the difficulty of getting the revolutions with the extra immersion of the wheels, the engines have not developed their full power; and also from some little heating of the bearings, which is not unusual in new engines. In fact, the ship has only been under steam three times, and a little more experience is required before she can be driven at her utmost speed.

Mr. J. Scott Russell: You have not mentioned the actual speed.

Mr. E. J. Reed: She has steamed, we believe, at 16 knots; but, as I say, we have not

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developed the full power and have not yet made a trial of her speed. She attained that speed the other day on the run round from the Humber to the Thames at the last port, but I need not say to the gentlemen present that it is quite impossible to state what the ultimate speed will be until you put the ship on her trial under all the circumstances of a trial trip, which we have not done. On our trip the other day the pilot told us by his running from the land that we were steaming at that speed; but I must say that we have no guarantee beyond the pilot's account judging from the lights and the land that we passed. It may have been a little exaggerated, but I must say that I see no reason whatever to doubt that the speed of the ship will be high, at any rate I hope in excess of the existing vessels, and then that object which was the primary one will have been accomplished.

The CHAIRMAN: How long will this vessel be crossing the Channel?

Mr. E. J. REED: I hope, my Lord, very little in excess of the hour—perhaps a little longer—because of the extra draught. As I stated at the outset the object has not been so much to attain a particular speed, as to obtain a high and surpassing speed, and the proprietors of the ship have much preferred to allow Mr. Bessemer and themselves to embody in this ship all the improvements and views he had, in order to test the great principles which the ship is built to decide, than to adhere strictly to the original elements of the design.*

My Lord, as I stated, there are other points of interest in connection with it, but I think, after the long time I have trespassed on the Meeting, I should not go into them. With regard to the saloon, I was not going to say anything, for the simple reason that it is entirely the construction of Mr. Bessemer, and he is the person in whose hands the whole responsibility of it lies; but Mr. Bessemer, I am grieved to say, has just telegraphed me to state that he is suffering from bronchitis, or otherwise he would have had much pleasure in appearing here to-day, and speaking on the subject. In his absence, I would just make a few remarks with regard to it, although I really do not know what to say, except that it is a very large and handsome room, supported on longitudinal pivots and moved by hydraulic power. It may be of interest to mention the manner in which the power is applied:—We placed the pivot of the saloon at what we considered the best height, and the whole structure stands upon a framework, of which the basis is formed of deep plate beams. These beams look large, and they are large and heavy, and I have no doubt myself that if Mr. Bessemer had been building this for the land instead of the sea, he would have had them larger and heavier still, because he would have preferred

* The speed of the *Bessemer* was subsequently found to be, at 8 feet 6 inches draught, 15½ knots or 18 miles an hour, the trial lasting for more than an hour.—E. J. R.

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to have had a considerable counterpoise of weight below. His machinery is so powerful that it is more inconvenient to deal with small forces by means of it than large. The power is actually applied at the ends of the two principal beams near the centre (*see* Plate II.) There are four pivots, one near each end, and two in the middle. The whole of the machinery is well described and illustrated in *Engineering* of this day, in which great pains have been taken to make known to the Members of the Institution the details of the whole affair.

There are one or two other points of interest which I ought to mention, because they are the points of connection between the ship and the saloon. The way in which this connection has been made is a very simple one. This is merely an india-rubber lip or flange lying against the saloon, with a drain pipe fitted below, with some little declivity, so as to carry into the bilges any water that may come through. The important point is to keep the public from getting there, as well as the little parcels and things which the public carry. That has been the principal object in this arrangement.

Another point of interest is this. When you stand upon the bridge deck of the vessel the saloon oscillates close to you, and it had to be considered how that should be dealt with, because the top of this saloon when the ship is rolling heavily would form with the bridge deck an immense pair of scissors which would operate unpleasantly upon the limbs and property of the passengers if it were not prevented. The manner in which that has been dealt with is this. A circle has been swept from the centre of the pivot of the saloon to the necessary height, and a coaming put upon the saloon and another upon the deck, so that the tops of those two coamings are always coincident in whatever position the saloon may be. As far as the rails are concerned they are kept at a distance apart, so that people must wantonly get between them in order to be injured.

At sea, when the saloon is worked, if it ever is to be worked, in a heavy sea—that is to say, if the ship can ever be made to roll very greatly—to the passengers upon the roof of the saloon the appearance will be most peculiar. Indeed, that is what we saw the other day; because you stand upon the saloon, and see the paddle boxes and the whole sides of the ship going up and down, while you are standing among them, looking on. My own feeling is, that it is extremely likely that one of the applications of this principle—which I believe may be made perfectly successful in every point of view—will be its application to small cabins. I think it will be an advantage in sea-going ships not to attempt to have a promenade deck on the top of the saloon at all; but in this vessel it is a most desirable thing, because a promenade is required for the traffic between the two countries. There are gallant and distinguished gentlemen here, who have seen the ship, and they can express their opinion upon her from that point of view.

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I must say, in the early days, I often heard it said that some persons thought the ship would be fairly successful, but that they did not believe in the success of Mr. Bessemer's saloon. My own belief has always been that Mr. Bessemer's invention might be made successful.

I believe that Mr. Bessemer has yet to find out the best means of inducing the eye and hand of the operator to follow the motions of the ship and some other motions of that sort, but that the saloon machinery has the power to control the saloon and to move it about as may be necessary, or keep it from being moved about by the ship, which is the main point, there can be no sort of doubt. I most earnestly hope and quite believe that in a short time this ship will be performing the Channel service with only one disadvantage, and that disadvantage will be that the ship in all ordinary circumstances will be so steady that everybody will be wondering why a saloon was required; and on the other hand I think Mr. Bessemer is placed in an unfortunate position, because, as I said in the early part, with a heavily-rolling ship, he could have applied his invention with success so much more readily, but with a ship rolling but little, and steadying herself in the curious manner which I have described between the rolls, it is extremely puzzling to the operator; but as I have said before I believe it will be a success.

DISCUSSION.

The PRESIDENT: I am sure you will all join with me in expressing our thanks to Mr. Reed for the very clear and interesting statement which he has given to us; and although that statement has taken longer than Papers usually do, I think that should not preclude any remarks which gentlemen may desire to address to us on what we have just heard.

Admiral Sir R. SPENCER ROBINSON, K.C.B., F.R.S.: My Lord and Gentlemen, I certainly should not have intruded myself at so early a period of the Discussion, but that I have an engagement which obliges me to leave almost immediately, and I should like to say a word or two on this subject which I have considered very much indeed. I therefore take the liberty of rising at once, although I know that there are many gentlemen in this room who are much better qualified to bring on the Discussion, to ask questions and elicit answers on the subject before us. I entirely concur in the favourable opinion which Mr. Reed has expressed of this great invention, for I cannot call it anything else. I can only reflect with pleasure on the difference between the object of this great invention, as we have heard it here so ably advocated to-day, and what we heard yesterday, when the whole zeal and spirit of every gentlemen in this room was concerned in bringing forward instruments of destruction of the most powerful character, when all the criticisms which we heard were that we were insufficiently armed, that our destructive powers were allowed to go to

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sleep, and that the combative spirit of this great country was considerably endangered by the negligence of those whose business it is to provide us with the means of acting defensively. For my own part I cannot deny that I considerably shared in some of the remarks that were made as to the want of classification of those methods of destruction which have occupied so much of the attention of naval architects of late years; but it is very pleasing indeed to-day to hear a lecture on a subject which, so far from dealing with questions of destruction and the misery of the human race, deals with a subject of the most comforting and soothing nature to those who have business on the great waters. Now, for the first time, we have a prospect of getting rid, or, if not getting rid absolutely, of mitigating very considerably those prodigious and indescribable sufferings which sea sickness brings about; and it was with very great satisfaction that I listened to-day to so eminent a naval architect as Mr. Reed, expressing his complete belief that the system of counteracting the motion of the ship by machinery, which has been put in action in the *Bessemer* for the first time, is not only likely to be successful in that vessel, but will lead to its adoption in vessels of a less costly nature on a small scale, but equally efficient in removing the dreadful sufferings and soothing the pangs of humanity, and inducing people to go more to sea and thus become acquainted with more of the world than otherwise they would. I do believe that the misery and suffering that most of us have seen and witnessed, if not felt ourselves, which the passage across the sea between France and England has caused, are really not to be described, and certainly cannot be exaggerated. I cannot for a moment presume to offer an opinion in contradiction to the opinion of so able a naval architect as Mr. Reed; but I confess that there is one part of the design on which he cast some little doubt, on which I myself entertain none. It is very presumptuous to say so; but as I have no doubt on that subject, and have been instrumental in various ways, more or less, in the Royal Navy, in bringing about ships constructed with low ends, I could not, with satisfaction to my own mind, refrain from entering some sort of protest against—I will not say the contemptuous, but—the rather disparaging view which Mr. Reed has taken of the low ends of ships. I cannot help thinking that for the purposes of Mr. Reed's design, the low ends of the *Bessemer*, which he does not like, are one of the greatest advantages the ship has. Not only am I of that opinion, but I think his own view of the case bears out what I say, because he could not have witnessed the ship's behaviour in a heavy sea, and the remarkable absence of pitching which she displayed in that heavy sea, without its having come across a mind so clear and enlightened that the low ends of the ship had something to do with that. The low ends of the *Bessemer* have been, in my opinion, extremely successful. I am not going to say that the whole of the remarkable absence of pitching which the *Bessemer* has displayed is owing entirely to the low ends; but I do maintain (and I think Mr. Reed did not say it was not so), that the low ends mitigate the pitching. As we have built ships in the Royal Navy of the most powerful capacity for offence and defence that can possibly exist—I am speaking of the *Devastation* class—and as those ships have been extremely objected to on account of their low ends, and many people in this Institution and out of it almost considered that the designing of such ships of war amounted to a crime (and, indeed, I have seen a Paper which stated that the person who designed such a ship was positively guilty of murder), I am glad to have the opportunity of stating, as a proof that I myself, in the advocacy of low ends, was not altogether wrong (because the object for which I especially recommended the design of the low ends was the absence of pitching), that the absence of pitching in this ship has been procured partly through the low ends. Therefore, I think it is not altogether out of place, and not very great presumption in me to differ as much as I have from Mr. Reed in stating that the low ends of the *Bessemer* are a considerable advantage, and will be

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found in the passage between Dover and Calais to contribute most remarkably to the steadiness of the ship. The advantage of the low ends is particularly great, because Mr. Bessemer has not yet brought to bear a method of preventing the vertical motion of the saloon, although he has brought to bear a method to prevent the horizontal motion. There is also a word more which I should say in defence of the low ends, in which I am sure that Mr. Reed and everybody else will agree. The low ends of the *Bessemer* obviate very considerably the difficulty of steering that ship when (and under many circumstances it will be so) one end of her is sheltered by a pier or by a projection, and the other end is exposed to the full force of the wind. Then the low ends of that ship will come into play with advantage and prevent the ship being twisted against her helm, which might otherwise happen. With regard to what Mr. Reed has said as to the admirable steering of the ship and her behaviour in a heavy sea, I had not the pleasure of being in the gale of wind which he was in, but I did accompany her out of the Humber, when we met with exactly the sort of waves which, in my judgment, she will meet with in the voyage across the Channel on most ordinary occasions. The pitching motion of the ship was absolutely *nil*, and the rolling of the ship was hardly perceptible. If you had looked from one end of the ship to the other, you would scarcely have seen the horizon move out of the line of the two sights. I think, therefore, that the lowness of the ends of the ship are not blameworthy, but that they are for the advantage of the service which she is intended to perform, and do reflect, I hope and trust, some little forecast on what ships of war with low ends may effect without risk and without danger, and with great efficiency to the service they have to perform.

Mr. E. J. Reed, C.B., M.P.: Allow me one word of explanation. I am afraid that I did not make myself quite clear, because Sir Spencer Robinson seems to have answered what I never intended to say. I said I was not a great admirer of low ends because of certain objections which exist to them, but I most distinctly intended to attribute the longitudinal steadiness of the ship to the existence of those low ends. In the case of the *Devastation* we raised the ends twice as high as in this ship.

The Right Hon. the Earl of Lauderdale, K.C.B., Admiral: I did not intend to take up the time of the Meeting, but the gallant Admiral, my brother officer, has set forth so strongly the advantage of low ends that I, being one of the old-fashioned sailors and in favour of high ends, feel bound to say something on the subject. The low ends are most objectionable, in my opinion, in an open sea-way; but I have no objection whatever to the low ends in the *Bessemer*, because the *Bessemer* in a passage across of twenty miles is never likely to meet any heavy seas, either from the East or from the West. The seas that come upon her will be from the South and the North, and therefore she will have a beam sea. All that I think you will require to do is to take care that no passenger or careless person can ever get on those low ends, because if they do they will never be seen again. With regard to the strength of the ship, it appears to me that her great strength consists in those irons running up angle-wise, in fact something on the plan of the great American river boats. The two ends are hung up by a chain entirely; they are very flat, and if you were to cut those chains, or anything was to happen, they would break in two. They draw very little water, the same as the *Bessemer*. The strength of the *Bessemer* must depend greatly upon these angle-irons, but in the American boats there are large chains. I think it was said, with regard to the motion of the saloon, or rather the no-motion of it, and the motion of the ship, that keeping the saloon in an upright position rather tended to check the rolling.

Mr. E. J. Reed: No.

Sir Spencer Robinson: It is the bilge keels that do that.

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The EARL OF LAUDERDALE: As to the bilge keels, there can be no doubt about it. In my opinion one-half of the whole secret is having continued bilge keels. I believe if you were to put more bilge pieces, you would not need to trouble yourself with the saloon, because it would be only the rolling which you would have to counteract; but it will have some effect in checking the rolling of the vessel. We find it on board the gunnery training ships, which we make roll by artificial means. We take a couple of hundred men and make them run across from one side to the other, and then set the ship rolling. As long as the men keep up and follow the motion of the ship, they gradually increase it. It will begin at nothing and will work up to seven or eight degrees roll; but if you stop the men, and when the ship is rolling on one side make them go to the other, and turn the weight over—it checks it. This saloon appears to be slung just like a compass card on a pivot, with a weight at the bottom. When that goes over, if it is checked by a man who attends the machinery, and is not allowed to follow the motion of the ship, I think it will have rather the effect of checking the rolling of the ship. I do not know whether I make myself quite understood. I do not understand how the cables are worked. Under cover, I suppose?

Mr. E. J. REED: From within.

Sir SPENCER ROBINSON: By hydraulic power.

The EARL OF LAUDERDALE: Where is the ship to lie at Dover in a north-east gale? Will she be on the lee side of the pier? Because, if not, it will be rather awkward lying there. The *Royal Sovereign* was there some years ago at a review. Her ends were 11 feet out of the water. When they were obliged to get under weigh no man could stay on deck. I merely mention this to show that if that vessel, with low ends, is lying in a north-east gale, she will be clean washed over her ends, and a good deal of the midship part also.

Mr. J. SCOTT RUSSELL, F.R.S.: If no one else has any information to give us on this subject, I will state one or two points which occur to me. In the first place, I am happy to be able, from a letter which I got from Paris a day or two ago, to get rid of one of the difficulties in this case. This ship draws a little more water, I am afraid, than you will always find at Calais. Although there may be still some defects in our harbour at Dover, they have provided deep water, and I believe they are going on now to provide deeper water. The good news I have to give Mr. Reed on this occasion is, that I have been informed that a negotiation is now going on between the Northern Railway of France and the Government and M. Dupuy De Lôme and some of his friends, for the creation of a new deep-water harbour at Calais. If that be done, as I trust it may be immediately, and as they appear now to think it is of great importance that they should have it, then one difficulty is taken out of the way of this ship; because, if this ship be too large for Dover, it is larger for Calais. The next point on which, perhaps, I may be able to correct what I will venture to call an error in Mr. Reed's opinion is this:—he is of opinion that the flat rudder put there, after the stern has been brought to a point, is a better mode of steering that class of ships than the other method, which makes that part a continuous line in extension of the ship's lines. Allow me to tell him, merely as a piece of information (because I am so much older a man than he is), that, before he began this business at all, we tried exactly what he has been doing here. We know its good points, and we know its bad points; and the other mode was the improvement we were obliged to resort to in order to get over all the defects of that improved method. And when we adopted this new method, we got rid of

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all our difficulties. I have not much to say about that, because Mr. Reed will easily be able to alter it; and I understand he has made another further improvement, which is bringing it back to the system we were driven to, but to which, on this occasion, he has not yet been driven to.

Sir SPENCER ROBINSON: She steers admirably.

Mr. J. SCOTT RUSSELL: So did the other ships steer admirably; but I would rather tell you in private a serious difficulty that has not been anticipated. The next point on which I would venture to express an opinion, is a point as to which I am in harmony both, I hope, with Mr. Reed and with Admiral Sir Spencer Robinson. A great deal of discussion—some of it wise and some of it unwise—has taken place as to ships with low ends, and especially with low bows. I wish to say, with Lord Lauderdale, that there are some things for which low ends are good, and some things for which they are bad, and that in each case you must select that which has the most advantages; and, therefore, the quantity of nonsense talked against low bows, and the quantity of nonsense talked in favour of them, is equally useless and beside the point. Mr. Reed made an admirable observation when he said, "If you give me all the "conditions of the ship, the ship builds herself." I have built vessels with low bows; I have built vessels with under-water bows; I have built vessels with high bows; and they are all equally good when they are all applied to the right circumstances, and equally bad when they are applied to the wrong. The only question, then, is this—Are these peculiar conditions, and are the circumstances for which this vessel was made, the conditions and the circumstances to which this low bow effectually contributes or not? Now if you will look at the peculiar advantage and disadvantage of the *Bessemer* saloon as here arranged, you will see at once it is the same problem which we discussed yesterday—the problem of a steady gun platform. There is the gun, and the ship is the platform. We agreed on various points on the subject yesterday. We also agreed on what the nature of the motion was which makes an unsteady platform, or a sickness-producing ship, shall we call it? The unsteady platform has unsteadiness of the following kinds. We know that it is lifted up and down by the sea—No. 1; we know it is moved backwards and forwards by the sea—No. 2; we know it is turned in a transverse direction—No. 3; and also in a fore-and-aft direction, unluckily, which is No. 4. This motion of lifting, which every ordinary rolling wave has, is not compensated; this forward and backward motion is not compensated, the motion of pitching is not compensated by the *Bessemer* saloon, and therefore it was just a case in which that motion should be reduced to the utmost by the making of low ends. If I have a fault to find with those ends for that purpose it is that swelling above which is unnecessary, and rather injures than benefits both the speed of the ship and the steadiness of the ship. And if there is a fault they should rather have been finer ends and acting less upon the water, because larger ends do act more upon the water. They are, however, as far as they go, good for this steadiness for which the *Bessemer* saloon in this case is not good, and therefore act an essential part. With regard to the *Bessemer* saloon, the point is this, and I say it from a liking for the *Bessemer* saloon and not the contrary. I warn my friends not to be too sanguine of its effect on the minds, on the nerves, and on the stomachs of the passengers for these reasons, that I am credibly informed that this up-and-down motion is that which affects the most; that the second motion is the one which affects the next most; and that it is only the pitching motion and the careening motion which are in this case corrected. But, as Mr. Reed has wisely observed, the matter can be carried further, and the next set of *Bessemer* saloons may have smaller cabins, and circular cabins, and in those a great many more corrections may be made than have been made in this; and I dare say they may be so

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much the better. I only beg to say that is a very simple way of not making the passengers sick. In a series of vessels which I made I took the very simple mode of making the beds on which the passengers slept not flat but hollow in the middle; and therefore as they laid, instead of on a flat bench, on a hollow circular bench, they were always at the right bottom, and they never felt that there was any tilt, and everything came right. The next point which is worthy of notice is the division of the two engines. That has, perhaps, some advantages. It is thought that that would have great advantages, but I am not sure that it was more than that it was expedient in this case in order to place the *Bessemer* saloon in the centre of the boat. Therefore I think we ought not to criticise that upon any other ground; and as they are only separated from each other by the least possible distance, I think it may be a wise arrangement. Further I beg to say that in some respects I agree with Mr. Reed. It does not follow that because the second wheel goes faster than the first that, therefore, there is a great loss of power due to that higher velocity, or that it practically means a much greater ship. I quite agree with him that one wheel after another wheel may be so arranged that they may both be very efficient; and allow me to quote my original example of the *Great Eastern*, in which you will see that the two powers one behind the other, are perfectly efficient, and each does its work properly; and allow me to add that each does its work so properly, that in order to decide that I sent out the *Great Eastern* from the works on her first trip with a printed note put into the hands of everybody, showing how many revolutions at a given speed the screw would make, and how many revolutions at a given speed the paddle-wheels would make, and how many revolutions they would make acting together. On the very first voyage, evidently having had no previous power to decide that question, the printed formula was an exact expression of their performance. Therefore on the same principle you may calculate the action of those two wheels and trust to the result. I think those are all the points which it is essential to mention, and I only beg to say that I look with great admiration on gentlemen who have the courage now-a-days to do a thing so new, in a manner so excellent as I think this has been done. I think altogether it is constructed very wisely, for Mr. Reed and his friends have tried first of all to make the ship a stable ship, and secondly to take advantage of any addition which the *Bessemer* saloon would give. There is one more point upon which I differ from Mr. Reed. I should not have liked the ship to have been made a much worse roller in order to give the saloon a much better chance of success, and I would say that the maximum amount of success of the *Bessemer* steamer would be to make the ship so stable in her own nature that the *Bessemer* saloon would be of no use. We have once heard it said that the greatest benefit a great man can confer on his country is to render himself of no use, and so I think the greatest benefaction that could be conferred by this steamer would be that the ship should be so steady as that the *Bessemer* saloon should be of no use.

Mr. C. W. Merrifield, F.R.S.: My Lord and Gentlemen,—I do not propose to detain the Meeting with any questions as to whether the prophecies which I made on a previous occasion concerning the success or non-success of the various plans brought before the public are likely to be realised, because that is a matter that must affect, in whatever way it is decided, my personal vanity very much more than it will result in anything that is useful to you; but I must say there still remain a few points with reference to the future to be considered, and it is a far greater pleasure to me to see the extreme probability of the anticipations of Mr. Reed and Mr. Bessemer and other designers being fulfilled than any of my own expectations. I think that what has been already done shows that the ship is in many respects certainly a great success,

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and in most other points that they anticipated likely to prove the greatest success. To come to details, I quite agree with what has fallen from Mr. Reed (and what I think must be obvious), that if you are to have capstans and anchors, as you must necessarily do, on the ends of the ship, there are some nautical reasons which make it extremely inconvenient—for instance, the difficulty of getting at them and so on. But from a nautical point of view, as we have already heard before hinted at by Sir Spencer Robinson, the lowness of those ends is an extreme advantage to the ship, and that is in entering such gutways as either Calais or Boulogne harbours, which are simply like canals running into the sea. Calais is somewhere about 110 yards wide, and Boulogne is somewhat less than 80 yards. Boulogne harbour is specially exposed to a heavy cross sea, and one of the great dangers of making those harbours—a danger which already on some occasions has been seriously felt by some of our passage boats, but still more seriously felt by some of the larger steamers that occasionally make them—is that when the vessel is half in and half out of the harbour the bow is under the lee of the pier, and the stern gets caught and thrown against the other pier, because when a large vessel is keeping the mid-channel in so small a gutway as that it has not very much room to clear either side. That I consider is a nautical advantage which is a set-off to a great many nautical disadvantages. With regard to the question of sea-sickness, I have certainly never thought, and I suppose few designers would think, that they would entirely save from sea-sickness those passengers whom one occasionally sees, by a peep into the ladies' cabin, preparing themselves for sea-sickness on a fine day before they get out of Calais harbour. I think to some persons the very idea of getting into a steamer at all causes them sickness. I have known them so in Southampton water in the very best of weather, and it is also quite possible that in certain conceivable seas, persons of ordinarily weak stomachs (I will not say the very weakest) may be a little troubled. I am sorry to say that I am troubled with sea-sickness myself, but as far as my observation has gone, I have always remarked that I could generally contrive to face any single sort of motion for a considerable time together. What bothered me most was not the excess of motion in any direction, but the continual variation of the motions against which I could not stiffen my muscles in any form whatever. I have swung, I will not say for hours, but at least for an hour since I have grown up, in a swing to try if the motion would make me sick, and it has not had the slightest effect upon me, and yet the up-and-down motion in swinging is quite as great as we meet with in an ordinary ship; and, therefore, I think, even if Mr. Bessemer does not succeed in eliminating all the motions he will have done a great deal for us if he has got rid of what I consider to be the principal one, namely, the rolling. The actual dipping of the ship—I mean the vertical motion of the ship up and down as a whole, which is almost the only motion that would be felt in the centre of such a large ship—has been unduly exaggerated, I think, in its effects. In the first place that motion in such a ship and such a sea is not likely to exceed 3 feet or 4 feet, and it is not a very rapid motion. I think there are some stomachs that will take a very disagreeable tone from it. I have always found the most inconvenient vertical motion to be not the up-and-down motion of the ship as a whole, but what is chiefly felt when you are at the bow and stern of a ship, and then you have the up-and-down motion not only due to the ship going up and down as a whole, but to its turning about on its own centre, the bow going up and down sometimes six or seven times as much as the ship itself does, and going up and down a great deal when possibly the centre of the ship may not move at all. For those reasons I think there is every probability of this ship being a great success in most cases where persons are subject to sea-sickness. I think still there are some extremely weak stomachs which may suffer from it. I will conclude by saying that it is a great satisfaction to me to see

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a design of this character brought before us by such men. It is extremely interesting to me to see the careful way in which it has been thought out by men who have brought to bear upon it every resource of modern science and modern knowledge; differing in that respect very materially from a great many designs which are brought before us in this room, and still more from scores of designs which are brought to me privately by inventors who fancy they know everything about their subject, and have failed chiefly in this respect, that they have taken no trouble to make themselves acquainted with the knowledge which is possessed by other people on the subject.

Mr. Benjamin Martell: Considering the great reputation of Mr. Reed as a naval architect, I feel that any remarks which I may make on the design of the *Bessemer* will have but little weight, but as the vessel was submitted to the Committee of Lloyd's Register to receive a class in their register books, I may perhaps be allowed to make a few observations upon her construction. When the drawings of this vessel were first submitted, the Committee at Lloyd's regarded the case of such a very exceptional design as one to which no rule could be applied, and they, therefore, instructed me to go to Hull and examine the ship and make a special report to them concerning her structure and strength. I feel it is a very great pleasure to me (because it is always pleasant to criticise favourably) to be able to say that in the whole arrangements of this ship, the mechanical skill which I saw had been brought to bear in order to carry out the peculiar design that was necessary under the exceptional circumstances, was most admirable; the workmanship throughout was unexceptionally good; and the quality of the material was also exceedingly good, as was evidenced by the severe test which had frequently been applied. The peculiar manner in which a large proportion of the plates (particularly those plates which were referred to by Mr. Reed, where a sort of suspension stringer is fitted) which form the low ends, are bent to a very sharp and excessive curve, caused them to be most severely tested, and the very satisfactory manner in which they appeared to have stood that test, and the very excellent quality of the material, gave great satisfaction to me in surveying the ship. I examined the continuous longitudinal strength of the ship, and the manner in which it was carried out; and the provisions made for safety in the way of bulkheads, and partial bulkheads, and in giving tranverse strength where you cannot get beams, are very excellent. In a length of 90 feet, where you could get no strengthening beams across either the deck or amidships, a sort of caisson frame is made at the side, giving great transverse strength, and the whole arrangement enabled me to make a most favourable report to the Committee, and on that report the Committee, after appointing a surveyor to specially survey the ship during her construction, were quite of opinion that she was a most excellent first-class ship and fit to receive the A1 character in their Register.

The Earl of Lauderdale: Perhaps you would have the kindness to explain how the loss of strength from having no beams for so many feet in length was made out.

Mr. B. Martell: The beams only give transverse strength—the beams do not give longitudinal strength, and the manner in which transverse strength has been afforded is by making the sides of the vessel cellular. You compensate for want of beams for a length of 90 feet by constructing the sides in that manner.

The Earl of Lauderdale: Such a length without beams was a thing quite unknown. Do you mean that without beams across you could make the ship as strong as if she had them?

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Mr. B. MARTELL: There is no doubt whatever about the transverse strength of the ship. In that part there are deep transverse and longitudinal frames giving adequate strength.

Captain R. A. E. SCOTT, R.N.: My Lord, I do not attempt to criticise the vessel's construction, because it is a magnificent structure; and all the details of course are admirably worked out. The stringer plates and other fastenings, as any man conversant with mechanics will see, are admirable. But I want to point out a difficulty with respect to the *Bessemer* cabin, namely, that a man below can never see the motion that the vessel is about to make. That to my mind seems a difficulty in the whole hydraulic arrangement. If an operator could foresee, as it were, the motion that the vessel was about to make, and so counteract it, I think that would be a very great step. In the case of a man steering, unless he has his eye on the ship's motion he cannot steer, and especially is that the case in a heavy sea where he has to watch the run of the seas each way. That is precisely the same sort of thing that the operator who will have to keep this *Bessemer* cabin upright will have to do. I think, however, there can be no doubt at all as to the steadiness of the vessel. The very fact of so great a weight as 180 tons being hung in her centre, a little below the centre of gravity, will of course take a great weight from the side. Generally when vessels roll, everything going in one direction, the whole weight is pressing against their side; but here, on the contrary, you have a large weight hung in the centre, and that is in itself a great element of steadiness. Looking at the length of the ship, one cannot but concur as a seaman with the advantage of her low ends. In the first place they are not heavily struck by the sea and hence the vessel is not retarded, and by being so light at each end she has great freedom from pitching. Mr. Reed has started a point as to the lowness of ends which I think might easily be got over by merely running a sort of grating platform out over the ends of the vessel, and I think this would be found a very great assistance in lashing alongside the wharves and entering harbours. As to working the cables, they can, as any seaman knows, be easily worked from below, but I foresee a difficulty in weighing the anchor, because it seems to me to be perilously near the rudder of the vessel. But that is a question merely of detail. Then with regard to the two sets of paddle-wheels running together; it first struck me in considering the question that the foremost wheel should be shallower in its immersion than the after one. Then I thought that as a vessel is seldom quite steady, and as there is a great distance between the two wheels, she would have the advantage that one set of wheels would always be telling upon the speed. These four wheels in turning round and striking upon the water would also greatly assist to steady the vessel. There will not be such length at either end beyond the paddles, and therefore not so much vibration as with one set of paddle-wheels only. Mr. Bramwell, before he left the Meeting, asked me to mention, which I am very happy to do, our experience with regard to the cigar ship. We went in her on a cruise. That vessel had very fine ends and a barrel-shaped frame. We were in a nasty sea, and although in a very small vessel, the pitching was almost *nil*. We could scarcely feel it, and there was certainly no uncomfortable motion. To my surprise, although the vessel was as round as a barrel in cross section, she did not roll when she was laid broadside to the sea, but remained perfectly upright in a sea in which most vessels would have rolled considerably. Steadiness was the remarkable feature of that ship. In common with others I felt sorry when the prolongation of patent was refused to Mr. Winans, the talented inventor of that vessel, because I think he was carrying out experiments which would have been very valuable to our own country. I do not forget that Mr. Reed has been the Chief Constructor of the Navy, and Mr. Scott Russell has anticipated what struck me very strongly, that in the *Bessemer* ship you

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have a steady central gun platform. I cannot help thinking that as Mr. Bessemer has turned his attention occasionally to warfare, he might have had an idea of that kind, because this movable portion of the ship is certainly a splendid gun platform. Then the question arises whether other gentlemen, who are equally patriotic with Mr. Bessemer, will not bear in mind the fact that the building of merchant ships able to carry a gun at sea might prove with our extended commerce of immense value to us.

Mr. Henry Liggins: If there could be one occasion more than another on which we all deeply lament the absence of that skilful naval architect, Mr. Grantham, who read at this Institution last year a Paper on the improvement of the Channel service, it is in discussing the subject now before us. I have taken a very great interest in all that I have seen and heard of this ship, and therefore I venture to rise to say a few words on the present occasion. Through the courtesy of my friend Mr. Reed, I have had the opportunity of seeing the *Bessemer* steamer in the Millwall Docks. It seems to me that there are many reasons why that ship should not roll or pitch to the extent that might have been expected in the gale which she encountered in coming round from the Humber to the Thames. It should be remembered that that gale was entirely from the eastward. Now a vessel with a beam sea is not likely to pitch very heavily, and, therefore, that is a reason why the pitching motion on that occasion was not so great as that of ships going in an opposite direction, and going, to some extent I suppose, rather more against a north-east gale. But at the same time much may be due to the great length and size of the ship, for she is a large vessel, and we should not expect a large vessel to pitch so heavily as a small one in only a moderate sea, because after all it was not a very severe gale, and the pitching motion could hardly have been expected to be considerable; nor may it be so to an extent sufficient to make people very uncomfortable in such westerly gales as one meets with in crossing the Channel. With regard to her rolling we should not expect a vessel to roll much if it is a long flat vessel with a light draught of water, and further protected by those two bilge pieces which for the last six years have been a subject which I have brought under the notice of this Institution in as forcible a manner as I possibly could. I have crossed the Atlantic in one of the largest steamers afloat fitted with these bilge pieces in order to prevent her rolling. I must say I have always thought that it is a great mistake to make a low-ended vessel to contend with the heavy seas which are constantly to be met with in the English Channel, and I cannot see that her speed is in any way improved by being in the position which Lord Henry Lennox stated in his letter to the *Times* that that vessel often was in coming round from the Humber to the Thames. Both ends were under water. Now, that a vessel can go the faster because she is carrying the weight of many tons of water on any portion of her deck, is to me incomprehensible. I do believe sincerely that that vessel will be in jeopardy in many of the heavy seas which are to be encountered in going to Calais and Boulogne harbours, where the sea does not run fairly and truly, but crossly and awkwardly, particularly in the broken water at Calais Pier. I believe that on occasions such as I have seen, that vessel will be so deeply immersed at that low portion forward that she will have a kind of lasso round her neck such as wild horses are caught with in the Pampas. That would act just as a lasso does with a horse, and a horse by means of a lasso would be stopped in his career and pitched over on his broadside. Such an accumulation of water may on some occasions be found on the fore part of that deck as will effectually check the vessel's progress, hold her tight for a moment, her stern will then swing away, and she will be in the same position as King Louis Philippe was, a quarter of a century ago, when, being in an unstable vessel in a gale of wind entering Calais Harbour, instead of going into the harbour, his Majesty and his vessel went clean through

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the pier, and if that vessel had not been a French man-of-war, with the strength they usually have, there would have been a more serious catastrophe than we have ever heard of in connection with the Channel service. I therefore think that the mistake is a great one, and I cannot see any analogy between the low bow of a passenger steamer and the low bow which I think for fighting purposes may be a desirable thing in a vessel like the *Devastation.* I think Mr. Reed deserves the greatest praise for the magnificent manner in which every portion of that swinging saloon is carried out. The ingenuity of the invention is equal to the reputation which that well-known man, Mr. Bessemer, possesses, and Mr. Reed has carried out his wishes in a manner that must command our admiration. But, looking now at the vessel as one for the travelling public, what do I see? That a small cabin comparatively, in a large ship, is constructed for the purpose of the rich few who cross the Channel, because I understand there is to be an extra charge for the use of that saloon, and I suppose also the deck above that. Now we have the example of railways which shows us that the larger number of travellers are third class, and that the next largest number are second class. Now, will the second and third-class passengers be in any way interested in the success of this saloon? I think not. Therefore, the great portion of the public, at all events, have not the interest which it is supposed they have in the success of this invention. But the notion that this saloon will prevent sea-sickness is to my mind utterly ridiculous. I have seen people sea-sick on board an Edinburgh steamer, lying alongside St. Katharine's Wharf, from the upward heave and downward depression of the vessel, and not from the motion which makes them put their best leg forward to prevent their falling. I speak from the experience of eighteen voyages across the Atlantic Ocean, and many hundreds across the English Channel. I have observed many cases of sea-sickness in others, although happily the sea never produced any ill effect upon me. I am satisfied that it will only to a certain extent mitigate the evils of the rough water of the Channel; and therefore, if there is to be an extra charge for the use of the saloon, it does not benefit the great travelling public. When I look to see what advantage I and others who are not sea-sick would get, I must say that I find the most inconvenient accommodation to my mind in every other part of the ship. The cabins for an ordinary traveller in that ship are inferior in ease and comfort to any of the steamers of the larger class which are now used in the Channel service. I allude more particularly to those between Dover and Calais, and Dover and Ostend. The Belgian mail boats are 225 feet long, while Mr. Reed's boat is only 270. I of course deduct 80 feet for the low freeboard ends, which are not any portion of the ship so far as the passengers are concerned.

Mr. E. J. Reed: You are quite mistaken upon that point, because one end of the vessel is a fine saloon.

Mr. Liggins: Then I apologise for having made that statement, not having observed it when I saw the vessel; but there are so many turnings, so many companion hatches, and so many up-and-down places in the ship, that I think it quite reasonable that even I, who have been on board ships all my life, should have overlooked some one place. It struck me that the comfort of the passengers on the deck of that ship (and that is where I should like to be on a fine day to enjoy the fresh air, and to get a beautiful view of the shipping around) was interfered with. The majority of passengers are not sea-sick, and they like to get a view of the sea, and of the shipping; and the accommodation for passengers at large seems to be inferior to that of the present vessels. And I will give you one particular reason why. If you look at the section you will see that the promenade on the main deck of the ship, between the outer cabins on the one side, and the saloon cabin in the middle, is narrow comparatively (it may be perhaps 10

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feet wide), and offers no opportunity to see the sea and the surrounding objects, but as the vessel goes rapidly through the water you will be in a cutting draught which would give everybody cold, and everybody will be dissatisfied; whereas if you mount up to the higher deck above the side cabins, you will find yourself exposed to the whole force of the wind that is blowing, without the slightest protection being afforded by bulwarks, nothing but an iron railing, through which any child would easily tumble. And there is a greater inconvenience than that—because children might be taken care of by their parents—and it is that you cannot take a lady on that deck, for there are no seats there at present, and even if you could take her there, and there was any wind blowing, her dress would be blown over her head. You want protection from the wind as well as from the sea to make the Channel passage agreeable. There must on breezy days—and breezy days are the most enjoyable days—be an amount of spray that will blow up there and make it unpleasant for anybody to sit without the protection of an ordinary bulwark, and there is the absence of a fine wide handsome promenade deck on the ship such as Captain Dicey's steamer has, which probably is the only merit that ship possesses, and which is not the case with this vessel. Therefore, generally speaking, I say that the accommodation in the *Bessemer* for the public who cannot afford the increased price for the extra comfort of the saloon will be most disappointing to the majority of travellers. That the *Bessemer* will be a fast ship, there can be little doubt. She ought to be, with double the power and double the engines that ordinary ships possess, and in addition to that she has the further element of speed, size; and if she does not perform the distance of 21 miles between Dover and Calais, in an hour and ten minutes, it will be a great disappointment to everybody. There are many details about the ship which rather surprised me. I am surprised to see that she should be expected to carry the great weight of hydraulic, or steam worked cranes. She carries four enormous cranes for the delivery of cargo and for the delivery and receipt of baggage. Surely it is not customary to put cranes into a vessel for the delivery and reception of cargo, unless those ships in the natural course of their work are discharging and loading their cargoes in the middle of a stream. Ships which discharge and take their cargoes at wharves, are loaded and discharged by cranes which are fixtures at the wharves or docks; but sea-going ships are not accustomed, as far as I am aware, to carry the weight of very large cranes such as we see here, which may be struck by a heavy sea and cause serious havoc, unless there is a better reason than it appears to me there is in this case where she goes alongside well supplied wharves with every accommodation for the discharge and reception of baggage. Then there are these important life rafts fitted at the sides, which are of a novel and odd construction. I wished that we had heard from Mr. Reed some description of how they are to be used and applied.

The PRESIDENT: I am afraid that I must remind Mr. Liggins that our time is progressing rapidly.

Mr. LIGGINS: Then, my Lord, I will leave the life rafts suspended there, in the hope that they will never have to be used. I think, on the whole, Mr. Reed should be congratulated on the admirable manner in which the ship has been constructed, for as a piece of splendid workmanship it reflects the very highest credit on our profession and on his country.

The PRESIDENT: I must now call on Mr. Reed to make his reply.

Mr. E. J. REED: My Lord, for the reason which you have mentioned, I shall be very brief in my observations. While thanking Mr. Scott Russell very much, and indeed all the speakers, for the

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kindness and generosity with which they have spoken of this vessel, I was a little surprised that Mr. Scott Russell should give us an evil prediction about these rudders.

Mr. SCOTT RUSSELL: Not an evil prediction.

Mr. REED: Well, so evil that he would not tell us what it was. My answer to that will be this, that my rudder is almost the universal rudder. Let any one ask himself whether that diagram which I drew to explain this, does not exactly represent the position of nearly all our iron-clad ships.

Mr. SCOTT RUSSELL: Certainly not if you look at the other section. In one point of view I agree, and in the other I differ.

Mr. REED: The only difference between that rudder and the ordinary rudder is, that that rudder is somewhat longer and shallower, because the ship is shallower. There is no other difference between this and other light-draught vessels.

Mr. SCOTT RUSSELL: There is an entire iron ring round that rudder which is not round the ordinary rudder.

Mr. REED: I must thank Mr. Martell for the very handsome manner in which he spoke of the vessel, for those observations which he was pleased to make will be extremely valuable, not only to myself, who am greatly pleased to have his corroboration in such a matter, but to the Company, the owners of the vessel, who, as we have heard, are likely to encounter some antagonism in the pursuit of their difficult enterprise. Captain Scott spoke of the difficulty of a man being able to anticipate the motion of the ship. That induces me to call the attention of the Meeting to a point which I did not mention, but which is usually forgotten. What the man has to do in this case is not to take the roll out of the cabin at all, but to keep the cabin steady. You will observe that the ship has no means of rolling the cabin except by the motion which it impresses on the axles of the cabin, and there are no means of giving a rotary motion to the cabin except by the friction of those axles, and by any amount of rotation which may be induced by the lateral transport of the axes. It is quite a different problem from having a cabin that is rolling with the ship and having to take that motion out, because all you have to do is to hold this suspended cabin in position without rotation and prevent the ship from putting rotation on it through the axles; and that is such a light amount of duty that I think Mr. Bessemer would have succeeded in his object so far as that part is concerned, by putting in machinery of much less power than he has, because there is so little to be done. That is a point of considerable importance. Captain Scott said that the anchor would be perilously near the rudder. When this end of the vessel is acting as a bow that rudder is held firm by a strong bolt and becomes a part of the vessel. The hawse pipe considerably overhangs the rudder, and I do not think there is any danger, because, if under any circumstances, the anchor should get a little adrift and swing and strike the rudder, it would be of no great consequence, for it would have to do a very great deal of damage indeed to interfere with the efficiency of the rudder. I was a little surprised at the speech of my friend Mr. Liggins. Any one would have thought from the tone of his observations that we had all committed some public offence in building this ship, and had been most neglectful of the public interest and accommodation. I am afraid that some of his remarks savoured a little of a want of perfect candour and fairness, and I will mention one. He said it was no wonder that the *Bessemer* did not roll going in one direction because she had a beam sea, but that it was quite natural that the other vessels should roll going precisely in the opposite direction with precisely the same beam sea. I am totally at a loss to

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appreciate the force of that argument. If two ships are going exactly in opposite directions and one has a beam sea, I should suppose the other would have a beam sea.

Mr. LIGGINS: If the sea was *quite* a beam sea; but I believe the wind was rather north-east, which would be more in your favour than it would be for vessels meeting you.

Mr. REED: If we are not speaking of a beam sea, but of some departure more or less from a beam sea, then my answer is that we had all those departures. Every one knows that in sailing from the Humber to the Thames you shape very different courses, and in those changes we put the sea into variations of position; and I must say that throughout the passage we did observe a signal absence of pitching in the *Bessemer* as compared with the other vessels. Of course what Mr. Liggins has said about the vessel being large is in her favour, but I may also mention that we passed large vessels, not perhaps so large as the *Bessemer*, but very nearly so. I think if Mr. Liggins will do the owners of the ship the honour, and give them the pleasure of his company, he will find that his idea about the sea coming upon the low deck acting as a lasso round the neck of the ship, and throwing her over, is entirely imaginative. The curious thing that I observe is how exceedingly little the sea that comes on the decks affects the ship, because it is not a deck where the sea can lie or impose its weight. It is a mere case of the sea washing across, and one of the interesting features of the ship is, that when the sea falls just short of the amount which washes across the deck she throws up a very moderate bow wave. You see the water being driven from her, and you stand behind the bow wave and look at the back of it. There is no tendency of any kind for the sea to get over the deck of the ship and hold her. It is a totally different thing, and I am sure Mr. Liggins will admit that to be so when he has seen how the ship behaves at sea. For that reason there is no accumulation of water upon her. The water rolls over the deck, and I am sure the mere witnessing of what happens would remove from the mind of such an intellectual man as Mr. Liggins any idea about its imposing any burden on the ship. The cause of the steadiness is not so much that the sea lies on the deck and depresses the bow, but that there is nothing to lift the bow up. It is the sea rising on the upper part of an ordinary ship's bow which lifts her; and there being no such bow in this case she is not lifted. With regard to the question of sea-sickness, I am not aware that I said anything about that. My opinion upon that subject simply is, that this ship will occasion much less sea-sickness than the existing ships, and that it will enormously diminish the discomforts of the Channel passage. It is not expected that she will cure the extreme sensitiveness of some individuals, of whom I am one. I have been almost sea-sick on the Caledonian Canal, but I went through several hours of stormy sea in the *Bessemer* without feeling in the least degree sea-sick for about eight or ten hours. With regard to the deck accommodation I am not surprised that Mr. Liggins speaks of the deficiency of the present accommodation, but I am surprised at what he said about the cabins, because there are several cabins in the *Bessemer* which are superior to those of any of the vessels now running, that I know of. With regard to the other cabins, one of these ends has a cabin deriving light and ventilation from the upper part of the vessel, and certainly a much better cabin than those of the second class existing in the vessels now running. Mr. Liggins is rather difficult to please. He says if people go on the deck they cannot see because of the deck houses, and they cannot sit down, and if they go where there are no deck houses there is no shelter for them. So that when we put a shelter for them he objects to that because they cannot see the sea, and where there is an elevated space, and nothing to interrupt the view of the passengers, he says, "Look how you expose the passengers." If we are equally wrong when we shelter the passengers and when we expose them, I am afraid we shall

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have to abandon the attempt to please my friend Mr. Liggins. Then he spoke of the cranes, and said there were four enormous cranes. I must correct him as to that. There are only two cranes, and those are at one end of the vessel, and the end of the vessel is not in the least intended, nor are the cranes intended, for cargo. It is simply that one of these ends is used as a hold for the passengers' luggage. That luggage will be placed in large boxes, and the cranes are intended to take hold of these boxes at whatever part of the wharf the ship may be, and instead of each individual element of luggage being subject to the present ill-usage, it will be lifted by a crane from the wharf into the hold of the vessel, and the cranes exist for no other purpose. I admit that they are large, clumsy, and unsightly-looking things; but I only hope those defects will be compensated by their being efficient. It only remains for me at this late moment, and impeding as I am the progress of other Papers, to thank the Institution for the very generous and kind way in which they have received my statement, which I feel, from the novelty of the construction of this vessel, might fairly have exposed one to a great deal, not merely of adverse but captious criticism, very little of which I have had on this occasion.

Mr. J. Scott Russell: Allow me to correct an error. I have not one word to say against the steering efficiency of these rudders. They will steer perfectly well.

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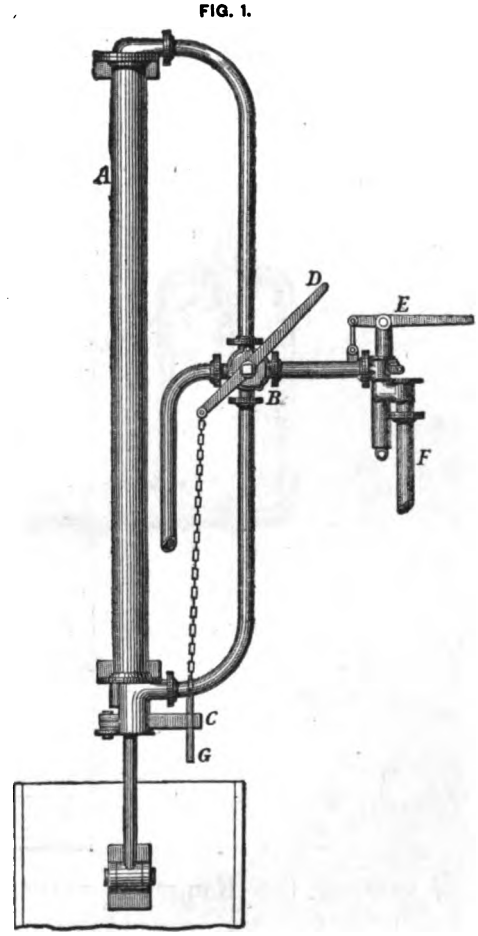
ON HYDRAULIC GEAR FOR WATER-TIGHT DOORS.*

By F. C. Coxhead, Esq.

[Read at the Sixteenth Session of the Institution of Naval Architects, 20th March, 1875; the Right Hon. Lord Hampton, G.C.B., D.C.L., President, in the Chair.]

Being well acquainted with the great difficulty experienced in closing the water-tight doors on bulkheads, &c., of ships, when occasion may require it to be done, I have introduced what I believe to be a more ready and expeditious means of doing so. I intend the door to be closed in about five seconds, and this to be accomplished by the minimum amount of labour, and without losing the control of the door during its descent. Should there be any obstruction to its descending it can be forced down to its seating; at the same time a ready and efficient means is provided for opening the door when all danger is past. Thus it will have the advantage of a quick descent, without the slightest risk of losing control, and furthermore there are no repairs to be made to the apparatus after such rapid action. This is accomplished in a very simple manner, by means of the apparatus here illustrated, in which A is a hydraulic cylinder; B is a four-way cock in communication with top and bottom of the cylinder A, and with the pump F, or other source of power, and also with a waste-pipe; C is a pair of clips for embracing the rod and supporting the door when open, which are held together by the pawl G; D is a lever

FIG. 1.



* Received 9th March, 1875.

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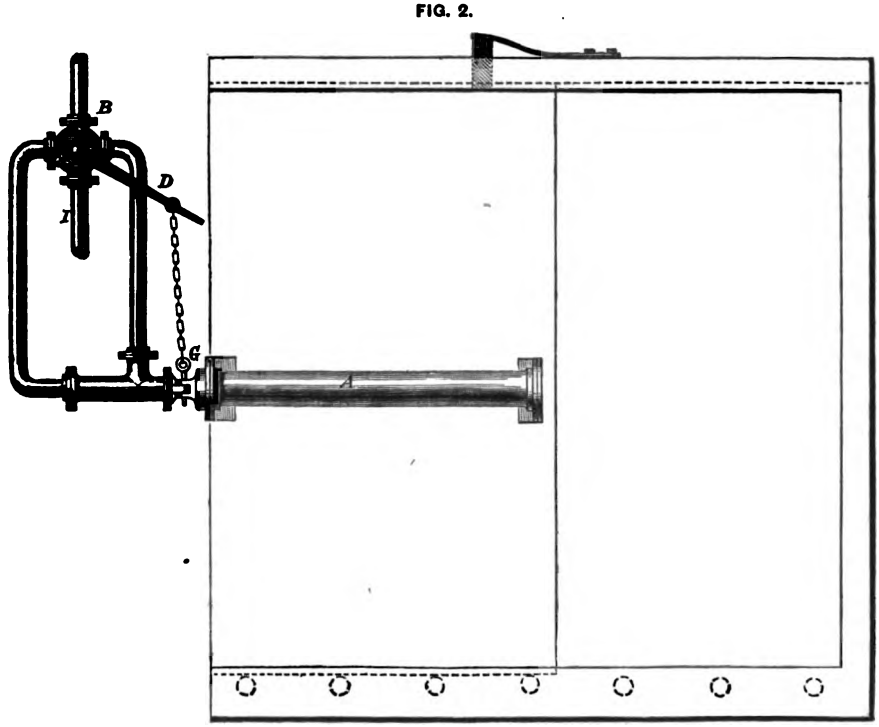
for reversing communications of cock B, and also for releasing the clips C, by connection with the pawl G by the chain.

The operation for opening the door in the first instance is thus performed. The handle of lever D is placed in the position shown and the pump F set to work, when the water, or other fluid, being forced into the lower part of cylinder A, the piston therein is caused to rise, and with it the door (by its attachment to the piston-rod), until it has obtained the required opening, when the pawl G by its peculiar shape will cause the clips C to close and embrace the piston-rod, and thereby support the door independently of the water under the piston.

For closing the door: The lever D is reversed, when the communications between the cylinder A and pump F are changed, the clips C released, and the door descends by gravitation, but is prevented from closing with a crash, by having to displace the water under the piston. Should there be any obstruction to its descent the pump F is applied.

For horizontal doors it is preferable to fix the cylinder A on the door, as shown in Fig. 2. The cock B can be put in connection with the water outside the ship by means

FIG. 2.



of one of the Kingston valves, and the force due to the ship's immersion made available for closing and opening the door. Where there is an objection to the height

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for vertical doors, as shown in Fig. 1, the cylinder A can be fixed on the door in the same manner as shown in Fig. 2; or two small cylinders can be fixed one on each side of the door, and connected by the piston rods to a crosshead on top of the door.

The above description of gear is applicable to ships of war or the larger class of passenger ships, and can be worked entirely from the main or any other deck. To meet the requirements of smaller ships, or those which do not carry passengers, and in which the crews are not quite so well disciplined, a means is provided for the door to act automatically. To accomplish this a float is suspended in the bilge by a spindle working in guide brackets attached to the bulkhead, and a stud is fixed to the bulkhead, on which is a lever. One end of the lever is connected to the float spindle, and the other by a rod and chain to the cock handle; hence, when water enters the ship, the float rises, and by so doing reverses the cock handle, thereby releasing the door, which then descends as before described, thus rendering the services of any attendant unnecessary. It can be easily applied to existing doors by taking off the old and putting on the new gear, the door remaining the same as before, without alteration. There is nothing about it which can become rusted up, or in any way seriously damaged, and thereby prevent its being fit for use when wanted. The pump F will be always fully charged with water, being fixed below the water-line, and the suction pipe attached to the supply pipe for cooling ashes when in the stoke-hole, or to the cooling pipe for bearings when in the screw alley or tunnel.

Should it be necessary for the vessel to go into very cold climates, glycerine can be substituted for water, by placing a small tank of it near the pump. In the case of steam ships, where high-pressure steam is used, the cock B can be put in connection with the lower part of the boiler, and power thus obtained for the purpose of closing or opening the doors. It is so arranged that a very simple index can be applied to show when the door is open or closed, and this index can be used either vertically or horizontally as may be required.

This new gear is being put into the imperial German iron-clad frigate *Deutschland*, now fitting out in the Millwall Dock.

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DISCUSSION.

Mr. J. Scott Russell: I think this plan is a very ingenious and simple one. I would ask one question, and that is, why Mr. Coxhead prefers that contrivance to a screw?

Mr. Coxhead: On account of the speed in closing. It is well known from the best authorities that you cannot close a door 6 feet high under 20 minutes, and that is time enough to sink a ship. This will close it in 6 seconds.

Mr. J. Scott Russell: For that purpose one might cut the string and let it fall.

Mr. Coxhead: But if it got part of the way down, and there was any dust, that would prevent its falling, and you would lose all control over it; but here you have a pump, and can force it down.

Mr. J. Scott Russell: That is quite true.

The President: As no other Gentleman rises to make a remark upon this Paper, it only remains for me to express the thanks of the Meeting to Mr. Coxhead for bringing the subject before us.

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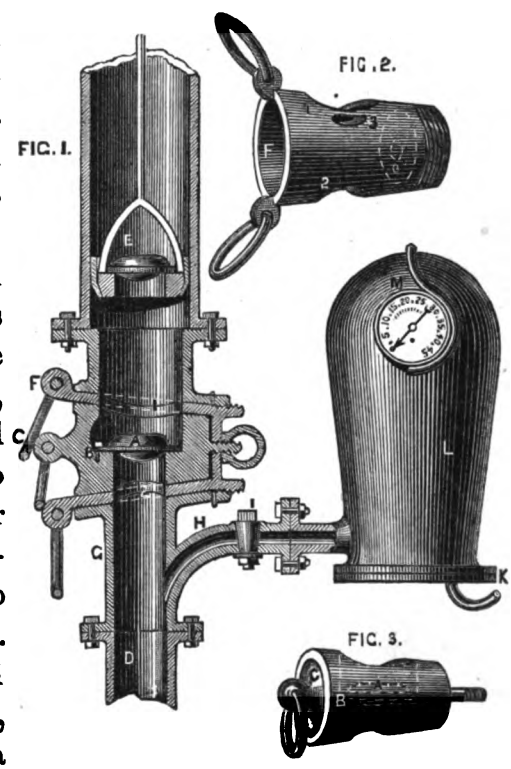
ON AN APPARATUS FOR CLEARING BILGE-PUMPS.*

By George Warren Sly, Esq.

[Read at the Sixteenth Session of the Institution of Naval Architects, 20th March, 1875; the Right Hon. Lord Hampton, G.C.B., D.C.L., President, in the Chair.]

Among the numerous and important questions pressing upon the attention of the naval architect for attaining greater security of vessels at sea, is that of how best to provide against such disablement of the pumps by choking as necessitates putting into port. To this end the author has designed an apparatus, shown in vertical section in the diagram. The suction valve A and its seat B are arranged within a transverse passage or way in a conical plug C. When the plug is in its open position, the passage or way through it coincides with the suction pipe D and pump barrel E. The plug is fitted and ground into a shell F (Fig. 2), having corresponding holes or ways 1 and 2, and an air hole 3, which shell is fitted and ground into a correspondingly formed suction-valve chamber or barrel G. Below this a pipe H, provided with a stop-cock I, enters the suction pipe from a force pump K, having an air chamber L, and a pressure gauge M. The plug is held in place by a screwed stud passing through the end of the valve chamber, externally of which the stud is provided with a nut, as shown. The plug is prevented from turning within the shell by a small pin fixed to the end of the plug and entering a corresponding hole in the shell. On turning the plug and shell in the valve chamber, communication between the suction pipe



* Received 26th February, 1875.

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and pump barrel is closed, whereupon the plug may be withdrawn for inspection, cleaning, or other purposes, without losing the vacuum or unrigging any other part of the pump, and the stopcock may be opened, so as to turn the pressure from the force pump into the suction pipe, for clearing it. The gauge will indicate when the suction pipe is clear. The strainer of the suction pipe may be washed out by the water in the pipe, without the application of pressure, by simply turning the shell so as to bring its air-hole opposite the suction pipe when the plug is out.

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ON A NEW CENTRE-BOARD YACHT.*

By Charles Hemje, Esq., Naval Architect of New York, U.S.

[Read at the Sixteenth Session of the Institution of Naval Architects, 20th March, 1875; the Right. Hon. Lord Hampton, G.C.B., D.C.L., President, in the Chair.]

Having noticed in the *Scientific American* that you solicit communications on the construction of yachts, I beg leave to address to you a few words on this subject, accompanying the same with a model.

For some time past yachting in the United States has been on the decline for various reasons—chiefly, I suppose, on account of the large expense of keeping such yachts as the *Sappho*, *Dauntless*, and others. It is not likely that any more yachts of that class will be built here; the future style of yachts will be the centre-board, or commonly called in England "racing machines." However these racing machines have proved themselves to be very good sea boats if properly proportioned, and although the present style of them has some very great disadvantages, we are in a fair way to overcome them, and will be able to produce a centre-board yacht complete in every respect. So far our centre-board yachts have had three great disadvantages, namely:—

1.—The centre-board trunk extending from mast to mast (in schooners) and entirely up to the deck, thereby dividing the principal part of the yacht in two parts, neither of them being large enough for a cabin and only fit for state rooms, &c., leaving but a very small cabin aft of the mainmast.

2.—Being compelled to place the centre-board between the masts, the centre of action of the same when down has invariably come too far forward, thus preventing the vessel from handling as easily as it ought to if the board was in the right position.

3.—The uselessness of the centre-board in a heavy sea, as it would be twisted off if entirely down; besides it would strain the trunk so as to start it leaking.

* Received 16th February, 1875.

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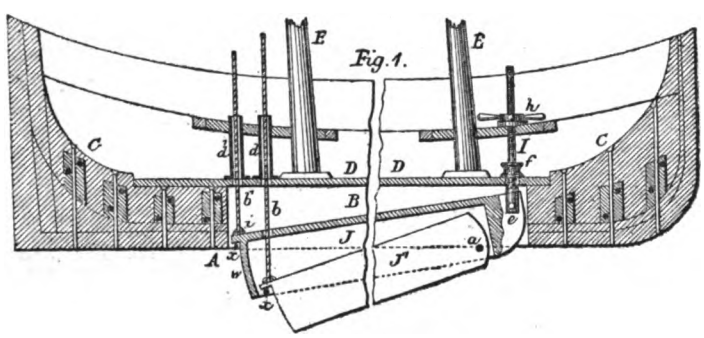
By examining the accompanying model you will perceive that all these difficulties have been overcome, inasmuch as the centre-board is entirely confined in the keel and keelson, with the exception of a small trunk aft of the mainmast which can be covered by a table, &c. And even this trunk can be avoided by constructing the centre-board of two parts, so that the one part shuts up into the other when hauled up. The largest and widest portion of the yacht is thus available for a cabin, the same as in a keel-boat; and as the masts do not interfere with the centre-board, the latter can be placed so that its centre of action falls in a line with the centre of gravity of the vessel. This kind of centre-board being longer and not so deep as the present ones, can be used with perfect safety in a heavy sea, and being made of iron its weight will add considerably to the stability of the vessel.

The keel and keelson as shown in the model actually form only one piece, firmly bolted together; the frames, which are made in two halves, each being mortised into the former and bolted vertically into the keel alongside the centre-board, and both vertically and horizontally forward and aft of the same. On the top of the keel a heavy cap is laid to close up the centre-board opening, as well as to serve for a step for the heels of the spars. Although this plan of construction was especially got up for centre-board vessels, it can as well be applied to keel-boats, especially as the sharp floor timbers are getting to be very scarce.



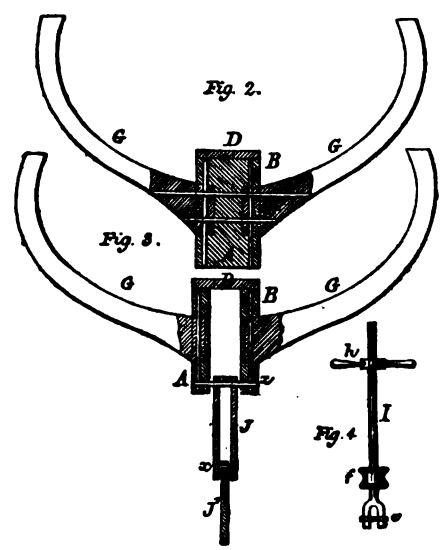


Fig. 1 represents a longitudinal vertical section of a vessel on my principle. Figs. 2 and 3 are transverse vertical sections of the same; and Fig. 4 is a view of the means for adjusting the front ends of the centre-boards.

In the building of the vessel I entirely dispense with the floor timbers, as now used, forward and aft of the centre-board trunk, and instead of the separate keel and

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keelson I bolt the keel A and keelson B firmly together, with no space between them, so as to form actually only one piece, as shown. The stem and stern posts C C are fastened to this piece in the ordinary manner. As far as the centre-board extends a slot or opening is cut longitudinally in the combined keel and keelson A B from top to bottom, and on the upper side of the combined keel and keelson a heavy rider D is laid and fastened to close the centre-board opening toward the inside of the vessel, as well as for the heels of the masts E E to stand on.

By this mode of construction the masts do not interfere with the centre-board, which latter can extend both forward and aft of the masts.

The frames G G are made in two halves each, the heel of each half frame being mortised into the sides of the combined keel and keelson, and can be bolted both horizontally and vertically, as shown in the drawing.

The centre-board used in this vessel is made of iron or other suitable material, and constructed in two parts, J and J^1, the outside part J forming a case over the inside part J^1 when the latter is hauled up, and both working in the slot or opening in the combined keel and keelson. The inner part J^1 is hung at its forward end on a bolt *a*, passing horizontally through the outside case J; and on the after end is suspended by a chain or rod *b*, passing through openings in the upper edge of the case and of the cap D, and through a flanged column *d* bolted to the cap, up to the deck. The outside case J is suspended at the forward end by a heavy vertical rod I, the lower end of which is forked to receive a part of the case J into it, a horizontal bolt *e* connecting them. On the top of the cap D the rod I is provided with a stuffing-box *f*, for the purpose of keeping out the water. The upper end of the rod, either above or below deck, is threaded, and provided with a screw hand-wheel *h*, or other mechanical device, for raising or lowering, as may be necessary. At the rear end the case J is provided with a rod or chain b^1, passing up through a column d^1, the same as described for the inner part J^1. The case or board J is closed at the rear end by a partition *w*, so that the entire case is closed except the bottom. The advantage of closing the bottom is that, when the vessel is in motion, the water is prevented from rushing in between the two parts, as is often the case where the rear is left open, and the board carried away.

By this means the centre-boards J J^1 may be used together or separately, as desired. When the chain or rod *b* is loosened the board J^1 will turn on the bolt *a* at its forward end, and its aft end drop down until a projection *i* at that end strikes a stop-bolt *x* in the case J. When the chain or rod b^1 is loosened the case J will turn on the bolt *e* at its forward end, and its aft end drop down until stopped by similar stops *x i*.

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For the purpose of getting more surface of centre-board the forward end can be lowered by means of the rod I, and by raising or lowering the forward end the action of the centre-board can be regulated and shifted backward and forward so as to suit the sailing qualities of the vessel.

The centre of action of the centre-board should be on a vertical line with the centre of gravity of the vessel, to make the vessel handle easily; and, as the centre of gravity of the vessel is not a fixed point depending upon the storage of the cargo, it is necessary to arrange the centre-board so that its centre of action may be made to correspond with the centre of gravity of the vessel. This is accomplished by the adjustment of the centre-board, as before described.

DISCUSSION.

Mr. Henry Liggins: It may perhaps be expected that I should make a few remarks upon this Paper; and, in doing so, I will say at the outset that I do not think the term "centre-board yacht" is quite the right term to apply to what I should call a drop keel. This is not strictly a centre-board yacht; but an elongated keel which we in England usually describe—as contra-distinguished from a centre-board—as a drop keel. It is on the same principle, but different in length. The drop keel is more than one-third of that vessel, and the centre-board is usually very short in its length, and occupies but a small portion of the keel. This is an old invention of an English naval officer, something like a hundred years ago; and we have for many years past abandoned it as useless as a general rule; but the Americans have adhered to it because they happen to have five estuaries and shallow water rivers suitable for pleasure sailing. Therefore they still retain the centre-board boats on account of the facilities which they have in the shallow waters for using them. We certainly do call them, as this gentleman very properly says, racing machines; and no Yacht Club in England, Ireland, or Scotland, allows them to be used for racing purposes, and for reasons which will be apparent to gentlemen who give naval subjects their attention. It would be a great mistake on our part if we were to have racing machines which would be utterly useless vessels. They might be made very fast, as centre-board yachts generally are, particularly in smooth water; but we exclude them because they would introduce a style of vessel which is not useful in encouraging the art of naval architecture. This boat is all very well in its way; but it is useless for racing purposes, and for this reason, that the length of it would make it very slow in stays; and a racing vessel slow in stays would have very little chance of winning a race against our fast cutters.

Mr. J. Scott Russell, F.R.S.: I think it is much less than the ship itself.

Mr. Liggins: But it is much too long as a drop keel to enable that vessel to come round quickly, as a racing yacht would be expected to do. This has been tried in England and found wanting. Three centre-boards have been used in one vessel—one in the middle, one aft, and the other forward; and it was

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found that the inconvenience of raising them was so great, and that so little advantage was gained by having three instead of one, that one centre-board has been adopted both in America and in this country. But that has really been a centre-board, and not a drop keel as this is—which drop keel, in my opinion, would prevent the vessel coming round in stays with that rapidity which racing yachts must have.

Mr. J. Scott Russell: I think this is one of the best possible inventions of the dropping keel, and for this simple reason—that it has some points of safety which the ordinary centre-board yachts have not, and that it has some points of great efficiency which the ordinary centre-board yachts have not. Allow me to state my experience on the subject. It so happens that I have seen a vessel of this kind many years ago almost exactly as this is, with the following difference—and the difference which I am going to explain is that which makes it either a good thing or a bad thing:—You know that our common yachts drop very much at the stern, and that a standard ordinary yacht draws 12 feet at the stern and 6 feet forward. That is sometimes a danger and an inconvenience; and the other day a friend of mine was shipwrecked with his whole family owing to that great difference of draught of water abaft. Now this is an invention which simply shaves off the extreme depth of the keel aft, does not touch it forward, and then allows a straight piece of keel to drop down exactly into that position which an ordinary racing keel occupies; and, therefore, that vessel thus becomes, if prolonged, a perfect racing yacht when it is dropped down. Allow me to draw attention also to another most important distinction. Our modern yachts are to a great extent built of iron. Permit me to say that in an iron yacht that keel would be prolonged the whole length of the keel; it would drop the whole length of the keel, and would transform that yacht of a light draught of water into a yacht with a full draught of water in a moment without difficulty. Let me call your attention to another great advantage. That keel being so dropped, and being there, if by accident you run aground in shallow water that keel is immediately pushed up in the gentlest possible manner by the gradual slope of the keel, goes into the hollow keel above, and will save such a shipwreck as that which, as I stated to you, overtook my friend and his family the other day from the extreme depth of keel.

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ON A NEW BASE FOR THE FORM OF VESSELS.*

By Edward Jackson, Esq., of Manila, Philippine Islands.

[Read at the Sixteenth Session of the Institution of Naval Architects, 20th March, 1875; the Right Hon. Lord Hampton, G.C.B., D.C.L., President, in the Chair.]

I beg to lay before the Institution of Naval Architects a new base for the form of sailing vessels and screw steamers.

My ideas having been formed in a place so far distant from the centres of civilization, and where there are scant facilities for study, they are chiefly the result of my own thought and experience. I should therefore have been diffident in addressing so well informed a body, had not my ideas been confirmed on a small scale by proof with vessels I have myself constructed of from 20 to 80 tons; had not my principles been confirmed by authorities I have since studied, whatever may be my deductions; and had I not found that, in as far as having the greatest breadth farther forward in the lower than in the upper water-lines, I but agree with the late Mr. Maudslay, although my base leads to a vessel of different form to that shown in his drawings.

Fig. 1 represents the base I propose—an infinitely acute-angled triangle A at the forward end of the figure, changing gradually into an infinitely obtuse-angled triangle B at its after end, the midship section C forming a right-angled isosceles triangle, though of course this in practice might be obtuse. In this figure the greatest draught is at the smallest beam, and the greatest beam is at the smallest draught; that is, the one end is held up by vertical, and the other by horizontal displacement. The midship-section lies at half the extreme draught and half the extreme beam, the entry and run both extend throughout the length, and the increase of beam and decrease of draught are reciprocal, so that the displacement and replacement of the water are equal and simultaneous.

For comparison I add (Fig. 2) the base in triangles of the existing system, in which the ends are chiefly sustained by the middle, the part forward of the midship-section is given to entry, and the part aft of it to run, so that if the one be lengthened the other

* Received 17th February, 1875.

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is shortened. Thus, in old vessels the run was generally long and the entry short, while in some successful modern ones the run is short and the entry long.

Into the question of the resistance of fluids I do not enter; though the system I propose will at once yield both the finest of entries and the finest of runs; but my object is to obtain in a vessel such a combination of horizontal and vertical displacement, as will result in great propelling power of sail or screw, and small increase of resistance in rough water.

My system being a peculiar combination of horizontal and vertical displacement, I must give a few lines to the examination of their qualities, prefacing this examination by some remarks on beam.

Beam is out of favour on this side of the Atlantic, and in truth, mere beam may not give horizontal displacement. Thus beam deep down in the water has the evils of the vertical displacement it approaches; lowering the immersed buoyancy it lowers the metacentre, and the centre of gravity has to be lowered with it. Or beam flaring above a load-water line comparatively narrow but adds to the righting jerk.

But of horizontal displacement—by which I mean a displacement so horizontal as to yield an approximation to a constant load water-section at a given draught—the lateral movements are perfect. It resists careen at the smallest angles, both by lee buoyancy and by weather weight, as is beautifully exemplified in the double-tube lifeboats; of which I have been assured by the men, no sea lifts the weather tube out of water, light as is the draught. It never *rolls into* the waves, but ever *undulates with* them, riding above them. Its action is *preventative. It is always easy and water-borne* on its water bed.

To these the lateral movements of vertical displacement—by which I mean that approach to it on which so many vessels are now built—form a complete contrast. Its form at the surface of the water offers little resistance to careen; its form below water entirely favours it. Never firm but often rude, for it is divided against itself, the low buoyancy wrestles with the low weights by which it is tethered. These as violent afterwards as at first sluggish, but exert great power after considerable heel, and then the form is not only rudely righted by them but even by the free side, which, however straight before, approaches, after inclination, the disadvantage of flare. Not *undulating with* the waves, vertical displacement *rolls* a vessel *into* the waves or the waves into her. Its action is *corrective. Weight stability in rough water is attained only by constant strain.*

I say weight stability, because this is necessary to vertical displacement; and here must be remembered a danger in the full bottom of the day, the temptation to ease

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motion by raising the centre of gravity; which, reducing weight stability, if the surplus form stability be insufficient, a moment may be reached in which there is no stability at all. I would not deny that such a vessel might be easy as well as safe, with an exact adjustment to determined load lines—always, however, subject to much change—of weights to metacentre and sail to weights; but such adjustment is in all cases difficult, and to the trader as a rule *impossible*, for he must take the quantity and kind of cargo he can get, and have it stowed as best he can, and the qualities of the vessel have often to be guessed at, for as a rule they are only found out by trial in more or less danger.

With sufficient horizontal displacement, on the contrary, it matters little what sail is carried or where weights are placed; the difficulty of stowage is reduced to trimming the vessel to a given load line. *She will be easy with heavy cargoes, and stable with light ones.*

Horizontal displacement has also the immense advantage to the trader of avoiding ballast, and the reserve of buoyancy at a given freeboard is much greater. But its small draught does not give lateral hold on the water, nor a sufficient after-draught for rudder or screw, and *in a head sea* it is at a *very great disadvantage* as compared with vertical displacement.

In the system I propose, by its peculiar combination of vertical and horizontal displacement, the advantages of the latter are retained, while its disadvantages are avoided. If such combination make horizontal displacement practicable, useful and speedy in all winds and seas, surely it should in time replace the present build of low bulk and meagre beam, the safety of which is so very much more dependent on strength, freeboard, and stowage, and which has given so many dreadful proofs of its danger.

Figs. 3 and 4 are drawings for a trading screw steamer—which I call the *Manila*—on my lines; the dotted cross-sections being those of the *Bremen*, from the *Encyclopædia Britannica*. The latter has a good rise of floor, and is far from being an extreme example of low bulk. I have made the *Manila's* displacement considerably larger, though she would avoid much weight of ballast. It will be seen that the *Manila* would have an unusually near approach to a constant load water section at a given draught, her metacentric height—longitudinal as well as lateral—being so great. The great reserve of buoyancy abaft the bow admits of a very fine load line forward, yielding a bow which could be driven with great power against a heavy sea. Besides easy and diminished motion, the *Manila* would have the following advantages: I call particular attention to 6, 7, and 8, as being of great importance in trading vessels:—

1.—Clean run to screw, and its more constant immersion.

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2.—Great sail-carrying power.

3.—Great weatherliness.

4.—Straight course from after-gripe, and yet quick to helm, from constant immersion of the rudder in "solid" water. Less excess of after-draught necessary for after-gripe, as the great height of the displacement aft leaves great fineness below.

5.—Great cubic capacity for passengers and measurement goods, and this can be unusually increased, as the great resistance to extra sidewise immersion, and great lateral hold on the water, will admit so large an amount of superstructure; for horizontal displacement is safe with either a very high freeboard or a very low one. The weight-carrying capacity can be greatly increased by small increase of immersion, and yet the draught need not be great, the necessity for much, if any, excess of after-draught being avoided.

6.—Much greater equality of draught when loaded or when empty, and very great saving in expense, time, weight, and room of ballast—the tax of the shipowner.

7.—She would stow herself; being easy with heavy cargoes, and stable with light ones. There would also be less danger of shift of cargo.

8.—Greater body above water—reserve of safety—at same freeboard, and greater safety at the same reserve of buoyancy or body above water.

The *Manila* would certainly cost more to build, but this expense would, in most trades, soon be recovered in saving in ballast, and in great cubic capacity, and I trust that we are approaching the day when men's lives will be taken into the account, and when the designer's object will not be to get the largest displacement in the smallest dimensions of length, beam and draught; which means in plain English the greatest weight in the smallest size, manifestly the form of least buoyancy.

In Figs. 5 and 6, I add a yacht, the *Filipina*, of 93 feet load water-line by 26 beam. The dotted sections are of the *America*. I make comparison with that celebrated yacht as one of the fastest of her length; and the comparison is the more difficult for me, as she had great beam, form stability, and sail-carrying power. To the last indeed I attribute her speed, for though her entry is exceedingly fine, yet her run is short if not coarse. It will be seen that the *Filipina*, with more effective sail-carrying power, has a finer entry, a much finer run, a much smaller midship-section, and a much greater lateral resistance in proportion to the longitudinal resistance. Her metacentre is exceedingly high; she would possess in an extraordinary degree the advantages accruing from a load water-section little liable to change, and her form

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above that line is of little comparative importance. If besides lateral capacity and fine deck room, great overhead height be needed, any necessary superstructure can be added as already explained. With very small low-bulk she has room for the little metal ballast she would require.

It must not be thought that because I have made her displacement small, it could not easily be increased. Very little more immersion would make her displacement as large as the *America's*, while her draught would still be less: or a greater width of shoulder would at once increase her displacement and her sail-carrying power. But in my combined system sail-carrying power and speed, though against a head sea, can be obtained with small displacement, and all excess of displacement would be waste; whereas to obtain those qualities in weight stable yachts, a larger displacement is a necessity. I think that my drawings and explanations prove that I have *just reason* in believing that a yacht may be designed, on my base, which shall combine the qualities known to give *speed and ease*, *in all winds and seas*, in a degree unattainable in lines on the existing base.

Though probably the *Filipina* could well bear it, she would suffer under the R. T. Y. C. Rule, which, favouring any amount of ballast and draught, puts an extra penalty on beam—the escape from those evils—and thus produces a comparatively useless type of vessel. I think a fairer rule would be to tax length alone, and to leave to preventative and to curative stability a clear stage and no favour; for there is little fear of vessels of mere shallow beam ever coming into favour in the rugged seas that surround our islands.

Addendum.—Figs. 7 and 8 are comparisons between vessels of combined and of vertical displacement. Fig. 8 shows cross-sections at first, second and third fourths, with contrast in the position of heavy cargo on the floor. Fig. 7 shows the same sections where vessels are light:—the combined form assuming lines like a yacht's, and retaining stability, after draught and vertical entry; whereas the vertical form becomes deficient in stability and screw draught, and its forward section becomes so shallow that it has the disadvantage of horizontal displacement against a head sea.

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DISCUSSION.

Mr. J. Scott Russell, F.R.S.: All that I have to say can be said in one word. I cannot conceive a more exquisite ship than is shown in the drawing, or one with more good qualities.

Mr. Henry Liggins: I cannot sit still, my Lord, while I hear the Royal Thames Yacht Club Rule alluded to as it has been, because, as Official Measurer, I have measured as many as five yachts in one day for racing purposes, under that Rule, which has not been at all fairly described here. It is well known that it is the only practicable Rule adopted in the whole world where racing yachts are used. The Americans have tried all sorts of arrangements, and so have we, and they do not now use the Royal Thames Yacht Club Rule; but they have not found that fault with it which might have been expected from yachtsmen who wish everything different from us. Then I find a higher eulogium passed on the *America* yacht than she deserved. She was a vessel of 200 tons yacht measurement, and beat all the family yachts, not having any racing craft of her class against her.

Mr. J. Scott Russell: I beg your pardon. We have had many vessels of her class. It was a yacht of mine that was beaten, and therefore I may express an opinion.

Mr. Liggins: I think you are alluding to the *Titania*. Well, at any rate I was going to mention this fact—that a 60-ton English yacht in a fair sailing breeze beat the *America* yacht. I can quite understand that the *America* won her distinction in her one race round the Isle of Wight which gave her that high character which she deserves; but there can be no doubt that that success was due far more to the cut and set of the sails than to any other element of usefulness in that vessel; vessels that have been built since on that plan have not been as successful as many of our more recent large yachts. We now have yachts built of great importance, therefore the subject should be studied with great care. Gentlemen in England are building yachts of 400 tons. They are schooners of the greatest magnificence both as regards form and usefulness. There is no lack of those elements which are required on our stormy coasts. They are not long, narrow-shaped vessels, but they possess all the elements to make them perfect in any seas they may encounter in any part of the world. I should only be too proud and pleased to be sent down to Gravesend to measure that gentleman's yacht against any yachts of the Royal Thames Yacht Club. I am quite certain she has no possible chance of winning a race, under any fair plan of time allowance, against any of the crack yachts that now float with so much honour around the coast of England.

Mr. J. Scott Russell: I agree in the extremely damaging effect of the present Rule, or the past Rule, of measuring yachts, on the form, proportion, and sea-going qualities, and think the sooner it is altered the better.

Mr. C. G. Gumpel: I can well understand that Mr. Jackson has followed out this subject very closely; but I may tell him that he is not the first one who has hit upon this form after an *à priori* consideration of the laws that govern a vessel passing through water. On a former occasion when this subject was mentioned I asked myself these questions. How must the water be displaced, and how will it fill up the gap which an advancing vessel makes? The least quantity of water we disturb in passing through it the better. The way water will yield will always be to the surface. The depth of the water will

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always be our guide in determining the displacement of the water. For that reason it would be better rather to have the U bow which Mr. Reed introduced, I think, for displacing the water, so that we get that displacement which Mr. Jackson advocates; and, for the filling up of the gap which the vessel makes, to have the floor rising gradually from fore to aft. If you scoop the water out as an advancing vessel will do, and consider the gap formed, you will find the water will close in behind the vessel with greater force from below than at the sides. The consequence is that, when you build a vessel with a floor rising from fore to aft, the water will close in better and give greater help to the progress of the vessel through the water. That is exactly produced in the form of Fig. 1; and as an amateur shipbuilder who likes to meddle in these things, I myself have thought this form over and have partly adopted it; but I was afraid of doing it to the extent which Mr. Jackson has done for this reason: the beam in his vessel is all aft, and if you put sail power on her you will find that an enormous twist will ensue.

Mr. Jackson: The beam is not carried very far aft; the plans are not so extreme as the base.

Mr. Gumpel: At all events that was the consideration that guided me in limiting this principle. I believe that that form would not always be the best form for carrying greater sail power than ordinary yachts, nor would it increase the carrying power of a vessel.

Mr. Jackson: I have thought that twist might result from greater form stability aft than forward. But it will be seen how carefully I have guarded against inclination, and where there is little inclination there can be little twist. With regard to the rest, I have received such high praise from such high authority, that I can leave the *America* and the Rule of the Royal Thames Yacht Club to take care of themselves. I hope that I have drawn a vessel which will have the desirable qualities—swiftness, safety, comfort, and effectiveness; at any rate, I trust that my base may lead to their attainment.

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ON SELF-ACTING SAFETY CLEATS, FOR HOLDING THE SHEETS IN SAILING BOATS.*

By A. B. Cruickshank, Esq.

[Read at the Sixteenth Session of the Institution of Naval Architects, 20th March, 1875; the Right Hon. Lord Hampton, G.C.B., D.C.L., President, in the Chair.]

Among the numbers of new inventions which, in these modern times, are being brought before the public, ought not those inventions which have for their object the saving of human life from accident to have the first consideration? But it is not so. Those inventions which are for saving or making money are, in most instances, eagerly rushed after; and the inventor soon gets repaid for his trouble both with money and honour.

But in the case in which the invention relates to the greater safety of human life, most people will not trouble themselves about it, and the inventor has to see his hopes of getting his invention universally adopted frustrated.

The invention which I now bring before you is intended to make boat sailing safer than it is at present, by means of a self-acting cleat, which of its own accord slacks away the sheet of the sail when the pressure of the wind on the sail is sufficient to capsize the boat.

Most of the sad boating accidents, which are continually occurring, are caused by the boat upsetting when struck by a sudden squall. Now, this does not only happen when the boat is in the hands of inexperienced men; time would fail me if I attempted to enumerate the numbers of cases in which sailors, fishermen, and experienced boating men have been drowned from this cause. Some will say that the sheet should always be held in the hand; but what yachtsman or sailor, however careful he may be, will not be tempted to belay the sheet at times? And how many there are who nearly always keep the sheet belayed.

Even supposing that in every boat the sheet was always kept in the hand, would it

* Received 27th February, 1875.

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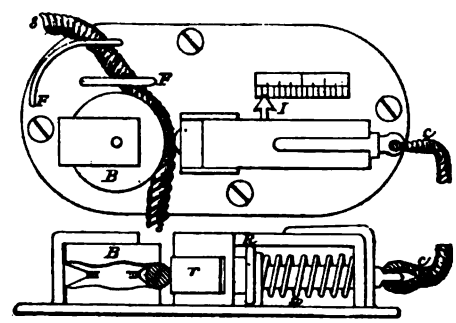
not be much better to have a cleat that will do the same work as a man's hand, and slack out the sheet when required? Why should not a safety cleat be as essential to a sailing boat as a safety valve is to a steam boiler?

We now come to the description of the diagram, which represents an A-sized cleat half its actual size. The sheet of the sail (*s*) passes from the sail under the fairleader bars (F F) to the barrel (B), round which it takes a quarter of a turn; there is a V-shaped groove in the barrel, which also runs in a zig-zag direction around it, so that, when once the sheet is in the groove, it cannot escape until it causes the barrel to rotate. The barrel (B) is an eccentric, working from $\frac{1}{8}$ inch in the smaller sized cleats to $\frac{1}{4}$ inch in the larger ones off the centre. A spiral spring (*sp*) on a rod causes a slide, containing a roller (*r*), to press against the barrel (B), and so keeps it from rotating.



When the strain on the sheet is excessive, the spring is overcome, the roller in the slide is forced backwards, and the barrel rotates a turn, slacking out the sheet, and so on, until the boat is sufficiently eased, when the sheet is held tight again. There is a regulator (R) which screws up and down the rod on which the spring is, by means of which the spring can be screwed up, so as to offer any degree of resistance that is required to the rotation of the barrel. There is an indicator (I), which moves along a graduated scale and shows how far the spring has been screwed up. In order to give facility for slacking out and hauling aft the sheet to trim the sail, a cord (*c*) is attached to the rod on which the spring is; pulling this cord draws the slide with the roller (*r*) in it clear of the barrel (B), throwing it out of gear.

For hauling aft the sheet the cord (*c*) can be made fast to a small rocker cleat, which will hold the cord fast when a single turn is taken round it. The cleat may happen to be so fixed in the boat that the cord will not lead to the steersman; in such cases the cord (*c*) is rove through a small fairleader block, and it can then be led to any part of the boat. The sheet can be cast off the cleat by merely pulling aside the roller (*r*) by means of the cord (*c*), and taking the sheet out of the groove in the barrel and from under the fairleader bars.

On first trying the cleat, the spring should be kept pretty slack, and gradually screwed up, until it is seen what pressure the boat will safely stand. The indicator then shows on the scale the proper distance that the spring should be screwed up. When running before the wind the spring should be screwed up a little farther than when

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sailing with a beam wind; but the proper positions of the indicator, with the wind from different points, is easily ascertained after a short trial of the cleat. The springs of these cleats are made of a peculiar kind of brass, specially made, so as to be very springy.

These springs retain their elasticity quite as well and as long as if they were made of steel, and their durability is as great as steel ones; and, of course, they are not liable to corrode from the action of the sea water. The cleats themselves are made entirely of brass, and lacquered.

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CONCLUDING PROCEEDINGS.

CAPTAIN SYMONDS, R.N.: The motion which I have now the honour to propose is a vote of thanks to his Lordship for the able, kind, and impartial manner in which he has presided over our Meetings, not only this year but hitherto; and I am sure that we are all grateful to him for the benefit which his kind services have conferred upon this Institution.

Mr. JORDAN: As a Member of this Institution I have great pleasure in seconding this vote of thanks. I am sure we all feel deeply indebted to Lord Hampton for the great kindness which he has shown us in again presiding at these Meetings. It is a great pleasure to all of us to see him here year after year, giving both his time and attention to our interests in this Institution.

[The Resolution, having been put to the Meeting by the Secretary, was carried unanimously.]

The PRESIDENT: I beg to express my very high sense of the kindness which you have shown in passing this vote, and I assure you I speak with all sincerity when I say that I ought rather to express my thanks to you than to receive thanks on your part. This is the fifteenth occasion on which I have had the honour of presiding over this most interesting and, I hope I may say, rising Institution. I can assure you most sincerely that, during the whole of that time, I have been more and more impressed with the value of the purposes which this Institution has in view, and I may add that I do not think I have ever been more interested than I have been upon this occasion. We have had in the course of the last three days most important Papers brought before us, and I do not know whether I shall speak in flattering language or otherwise, when I say even more important Discussions upon subjects of the highest national importance. I need only allude to the Discussions which we had at the commencement on the great question (for it has become a great question, and every day is more and more becoming a great question) as to legislation with respect to the Mercantile Marine. The next great subject discussed here was scarcely, if at all, of less importance, *viz.*, the question of Marine Insurance. Then yesterday we had a Discussion which I had not myself the advantage of hearing. I am extremely sorry for it, and therefore, I speak from hearsay and not from my own personal knowledge with regard to the value of the Discussion on my friend Mr. Scott Russell's Paper with respect to the present ships of war in this country. And, lastly, this morning we have had a Discussion in the course of which our established rules were, by common consent, set aside on account of the interest attaching to the able Paper of my friend Mr. Reed, and the interesting Discussion which followed. Here, Gentlemen, I think we have conclusive proof, and I say it with feelings of the very greatest pleasure and satisfaction, that the annual proceedings of this Institution are tending to advance objects in which public feeling is deeply interested, and by which the public welfare of this country is greatly promoted. It is, therefore, with feelings of the greatest satisfaction that I have taken any part, however humbly, in promoting or assisting the deliberations of the last three days; and I can only assure you, in conclusion, that I am extremely sensible of the constant kindness and support which, during fifteen years, I have had the honour of receiving from the Members of this Institution.

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Mr. EDWARD A. COWPER: I beg to propose that the thanks of this Meeting be given to the Vice-Presidents and the other Officers of the Council of this Institution for their great and efficient work in controlling the proceedings of this Institution, subject, my Lord, to your excellent supervision and assistance. I think the Institution now has arrived at that pitch of success that we may congratulate ourselves upon the position it holds in the country. I think the Discussions are listened to with great interest by the public generally, and have a considerable effect, and a beneficial effect, in other places where decisions are obliged to be come to and laws laid down for the regulation of our commerce and the navigation of our ships. I beg to propose a vote of thanks to the Vice-Presidents, Council, and Officers of this Institution. There is only one regret, which I really must express, *viz.*, that I am sorry to hear we are about to lose the benefit of our Honorary Secretary's services. It was with very great regret that I heard that announcement; but I trust we shall not lose the benefit of his services so far as he can assist us in the future.

Mr. CHARLES G. GUMPEL: I beg leave to second this motion, which, to me, is a very agreeable duty, because, from personal experience, I can corroborate the impartial readiness and amiability with which I and others have been met by the Officers of this Institution. From our previous Assistant-Secretary, from Mr. Merrifield, and from Mr. Woolley, I have uniformly experienced a kindness, readiness, and impartiality which must recommend itself to every one, and, therefore, I have very great pleasure in seconding this Resolution.

The PRESIDENT: Gentlemen, it devolves upon me to put this Resolution to the Meeting, as there are no scruples of delicacy which prevent my doing so; and it affords me very great pleasure, because I am convinced that it is most thoroughly well deserved—*viz.*, "That the thanks of this Meeting be given to the "Vice-Presidents, Council, and Officers, for the interest they have uniformly displayed in the objects of "this Institution." I cannot do that without once more saying how I entirely concur in the feeling—which has been expressed by the mover of the Resolution—of deep regret in seeing Mr. Merrifield sitting for the last time in possession of the little desk where he has so long aided our proceedings. I am sure that everybody will hold up their hands in favour of this vote of thanks.

[The Resolution, having been put to the Meeting, was carried unanimously.]

Mr. C. W. MERRIFIELD, F.R.S.: I have reserved for myself the last motion—as it will be practically the last opportunity that I shall have of moving anything from this chair—and that is, that a vote of thanks be given to the Society of Arts for their liberality in granting us the use of this Hall. I take this opportunity of thanking you all very much for the exceedingly kind manner in which you have expressed yourselves respecting me. Although I am obliged to leave the Secretary's chair, the welfare of this Institution will not leave my thoughts. I have a peculiar satisfaction in proposing this Resolution myself, because no one can know better than I do, not only the great advantage derived from the kindness of the Society of Arts in granting us the use of this room, but also the uniform personal kindness, courtesy, and assistance which, on all occasions, we have received from all their officers, especially from Mr. Foster and Mr. Davenport. It is therefore with peculiar pleasure that I move that the thanks of this Institution be given to the Council of the Society of Arts for their liberality in granting us the use of this Hall.

Mr. H. LIGGINS: I rise with great pleasure to second this proposition; and I am quite sure we have derived enormous advantage from the courtesy of the Society of Arts in giving us the use of this

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most elegant apartment, which is the most convenient room in London that could be selected for our purpose, both for the day and evening Papers. It affords facilities for our personal comfort and convenience which no other room can supply, and, therefore, I think our warmest thanks are due to the Council for giving us year after year the accommodation which this building affords.

The PRESIDENT: We have now for so many years been in the habit of finding ourselves perfectly at home in this room, that we may forget how much we are indebted to the Society of Arts for allowing us to occupy it. It is owing to their great courtesy and kindness year after year that we are able to meet here; and I do not think it is possible to find a room better adapted than this to the debates which we hold within these walls. I most cordially put this motion to you, which I am sure will be carried by acclamation.

[The Resolution was then put to the Meeting and carried unanimously.]

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MEMOIR OF THE LATE SIR WILLIAM FAIRBAIRN, BART., C.E., LL.D., F.R.S.,

Honorary Member of the Institution of Naval Architects.

Sir William Fairbairn was born at Kelso, in Roxburghshire, on the 19th of February, 1789, and was educated at the Parish School of Munlochy. At a very early age he evinced great mechanical tendencies, and was always busy in his play hours making tiny boats, ships, water mills, and windmills. About the year 1803, his father was appointed manager of the Percy Main Colliery, at Newcastle-on-Tyne, and there young Fairbairn finished his early education under his uncle, the Parish Schoolmaster of Galashiels, and was then bound apprentice to the owners of the colliery, where he began at the age of sixteen to work for 8*s.* a week, and continued until he was twenty-one, when he went to London to seek employment. The influence of the trades unions, however, was so great there, that he tried in vain to obtain work, for though he was taken into the employ of Mr. Rennie, the action of the workmen soon forced him to leave. He therefore quitted London and went to Hertford, where he was employed for a time in building a windmill. That job finished, he again went to London, and was more successful than before, obtaining employment with Mr. Penn, of Greenwich, with whom he continued for some time; but eventually, in 1814, he made his way to Manchester, where he got employed as a working millwright, by Mr. Adam Parkinson, with whom he remained for two years, when he set up in business on his own account, in connection with his old fellow-workman Mr. James Lillie. They began business in a very small way, but Fairbairn's mechanical genius soon became recognised, and this, combined with Lillie's practical knowledge, made their firm so superior to the ordinary mechanical firms of that day, that they were not long before they had as much work as they could perform, in renewing and devising mill machinery for many of the largest cotton-spinners in the neighbourhood; and the improvements which they introduced into this branch of mechanical engineering placed them at once at the head of engineering millwrights.

After twelve years' hard work in this line, Mr. Fairbairn's attention was turned to the employment of iron for shipbuilding. Having been engaged by the Forth and

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Clyde Canal Company to enquire into the possibility of improving the speed of their boats, he made a series of experiments on the subject, which led to his studying the theory of naval architecture, and he at once saw the immense advantages to be gained by the use of iron in shipbuilding.

Several iron steamers had already been constructed, the first having been made in 1821; but these had all been built in pieces, and put together where required for use. Mr. Fairbairn, in the inland town of Manchester, in 1831, built a small iron steamer, which he had carried on a waggon through the streets, launched into the canal, and floated down to the sea. There not being, however, scope for any large development of a shipbuilding business at Manchester, he removed, in 1836, to Millwall on the Thames, where he established the Millwall Iron Works, in which the *Great Eastern* was subsequently built by Mr. John Scott Russell, into whose hands the works passed about the year 1850.

During the fifteen years, however, that Mr. Fairbairn carried on the Millwall Works, he undertook many valuable experiments on the strength of iron, which in no small way conduced to the improvement of iron shipbuilding. Experiments, too, were carried on there on the strength of iron tubes, from the results of which the calculations were made for the designs of the Conway and Britannia bridges. In the investigation into the laws deducible from these experiments Mr. Fairbairn was ably assisted by Mr. Eaton Hodgkinson. So valuable were his labours considered by the Royal Society, that in 1860 he was awarded the Royal Medal "for his various experimental inquiries "on the properties of the materials employed in mechanical construction, contained in "the *Philosophical Transactions* and in the publications of other scientific Societies." He also made many improvements in the practical working of iron for various purposes, such as the construction of boilers, in which he introduced the system of double flues and alternate firing, and also the method of stiffening boilers by means of rings placed close together.

In the year 1837 he made his first Report on the Strength and Properties of Cast Iron to the British Association, in whose Meetings he always took a most active part, and in 1861 was elected President of the Association at the meetings held in Manchester. He was one of the chief supporters of Dr. Birkbeck in the establishment of Mechanics' Institutions, and indeed was deeply interested in all schemes for enabling workmen to gain theoretical and scientific knowledge, often himself delivering popular lectures to them on various matters. His principal lectures were collected and published under the title of "Useful Information for Engineers." Among the numerous works which he

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wrote we may specially mention "Iron, its History, Properties and Processes of "Manufacture," and "Iron Shipbuilding."

In 1861 Mr. Fairbairn was elected an Honorary Associate of the Institution of Naval Architects, and in 1870 he was elected as an Honorary Member. He contributed several Papers to the Meetings on the Strength and Construction of Iron Ships, and on the Laws of Resistance of Armour Plates composed of one or more thicknesses, and in 1871 he made some valuable remarks on the present and past construction of the Navy.

In 1869 he was created a Baronet in recognition of the valuable services he had rendered to the country.

He died at Moor Park, in Surrey, on the 18th of August, 1874, in the 85th year of his age.

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MEMOIR OF THE LATE JOHN LAIRD, M.P.,

Vice-President of the Institution of Naval Architects.

Mr. John Laird was the eldest son of Mr. William Laird, of Greenock; in which place he was born, in 1805. Mr. William Laird, however, quitted Greenock soon after this, and, settling in Liverpool, took an active interest in the shipping trade of the Mersey, assisting in founding the Dublin and Liverpool Steam Navigation Company, and in 1824 setting up a boiler-making establishment on the Birkenhead side of the Wallasea Pool. Mr. John Laird was educated at the Royal Institution, Liverpool, and in 1828 went into partnership with his father. His name is henceforth identified with that of Birkenhead, and he might well be proud to sit in Parliament as the Member for a place which he could remember as a boy as a small and insignificant village, and to whose rise and development—as a rival almost of Liverpool itself—he had so much contributed. This rise, however, was not made in a day, but was the result of years of untiring energy and enterprise. Thus in 1829, we find the firm of William Laird and Son engaged in building a pioneer vessel of iron shipbuilding on the Mersey—a lighter of 60 tons burthen, 60 feet long, 13 feet 4 inches broad, and 6 feet deep. All who have studied the history of iron shipbuilding know the great opposition which it at first experienced, and can therefore appreciate the credit which is due to Messrs. Laird for the perseverance with which, having satisfied themselves of the superiority of iron to wood in shipbuilding, they overcame the numerous obstacles, and almost unconquerable prejudice which they encountered in their endeavours to bring it into common use.

The first vessels of any size which they built were made in pieces and put together at the places where they were intended to be used. These were the *Lady Lansdowne*—a paddle-wheel steamer of 148 tons built in 1833—and the *John Randolph*, built in the following year for Mr. G. B. Lamar, of Savannah, United States. The latter was the first iron vessel ever seen in America. In 1834, too, they constructed a third paddle steamer, the *Garry Owen*, of 300 tons burthen, which was the largest iron vessel afloat at that time. General Chesney's well-known Exploring Expedition up the Euphrates was fitted out in 1835 by Messrs. Laird, the *Tigris* and the *Euphrates*, vessels of 109 tons

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and 179 tons respectively, being built for that purpose. These two vessels were also built in pieces, and, having been transported across the Desert on camels, were put together on the banks of the Euphrates. These boats having proved a success, the East India Company determined to buy a steamer which Messrs. Laird were then building for Savannah—an iron vessel of 300 tons burthen. In the same year they built an iron steamer, *L'Egyptien*, for the Nile, which steamed from the Mersey to Alexandria.

The year 1837 may be said to have marked an epoch in the history of iron shipbuilding, for in that year Mr. Assheton Smith, whose opinion in naval matters was at that time so much esteemed, having previously expressed a disbelief in iron, was at last gained over to its side, and ordered an iron steam yacht of Messrs. Laird, of 362 tons burthen, 150 feet long, 22 feet broad, and 100 horse-power. A great stride was then made in the size of iron vessels, for the next ship built by Messrs. Laird was the *Rainbow*, constructed for the General Steam Navigation Company of London, for service between London and Ramsgate. She was 600 tons burthen, 185 feet long, and 25 feet broad, carrying engines of 180 horse-power. Hitherto Messrs. Laird had only constructed paddle steamers, but in 1838 they built a screw steamer, the *Robert F. Stockton*, fitted with an Ericsson propeller, for river service in the United States. She was, however, only a small vessel of 33 tons burthen, and therefore, being unable to carry sufficient coal to take her to America, she made the voyage from Liverpool to New York under sail.

In 1839 Mr. William Laird retired from the business, and his son, Mr. John Laird, who for many years had taken the active management, became the sole proprietor. In this year he contracted with the East India Company to construct for them a light-draught armed flotilla for river service; and shortly afterwards four vessels of larger class—two of these vessels, the *Nemesis* and *Phlegethon*, though only of 5 feet draught, carried 32-pounder pivot guns and rounded the Cape on the voyage to India, the use of sliding keels and a drop rudder enabling them to overcome all the difficulties which came in their way. They were afterwards of great service in the Chinese War. In 1841 Mr. Laird built his first iron sailing vessel, a barque of 270 tons.

Mr. Laird had repeatedly applied to the Admiralty asking them to try iron instead of wood, but it was not until 1839 that he succeeded in obtaining a favourable answer to his request, and was given the contract for the *Dover*, an iron vessel of 228 tons burthen, and three gunboats—the *Soudan*, *Albert*, and *Wilberforce*. Mr. Laird then built the *Guadaloupe*, a war ship of 800 tons burthen, for the Mexican Government, which was so favourably reported upon as to induce our own Government to order the *Birkenhead*, a frigate of 1,400 tons, and 560 horse-power, which was launched in January, 1846.

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In 1845-6, Mr. Laird built four fast steam vessels for the South-Eastern Railway Company, and in 1847-8, two for the improved mail service between Holyhead and Kingston.

We have thus briefly sketched the part which he took in the advancement of iron for shipbuilding purposes, and introducing iron vessels all over the world. To Mr. Laird's suggestion is due the placing of the *Garry Owen* at the disposal of the Admiralty, to make experiments on the difficulty of working the compass in iron vessels; and he also took out several patents for improvements, among which we may mention that for vessels with a rudder at each end, which has been extensively used both for gunboats and ferry boats, and another for the construction of river boats of shallow draught. At the same time he took out patents for watertight tunnels in screw steamers, now universally adopted, and for vessels of war with a peculiar form of bow to admit of carrying very heavy guns to fire right ahead, which is not unlike that adopted in the gunboats of the *Scourge* and *Cuckoo* class in the English Navy. During the Russian war, when a large number of light-draught mortar boats were required at the shortest notice, Mr. Laird built one in three weeks. About this time, Mr. Laird added to his business that of marine engineering, and established the Birkenhead Iron Works, on a new site occupying an area of about 20 acres. The history of these works is so well known that we need not enter into them here. Having consolidated the shipbuilding and engineering works, under the name of "John Laird, Sons, & Co.," he retired from business in 1860, and his sons have since carried it on under the name of "Laird Brothers."

During all these years Mr. John Laird was actively engaged in pushing the fortunes of Birkenhead, whose prosperity may be shown by the fact that in 1831 its population was only 2,569, and in 1861 it had risen to 70,000. It was mainly owing to his exertions that Parliamentary powers were obtained in 1844 to construct docks in Birkenhead. Under that Act he was appointed a Trustee, and with the exception of two or three years, he continued to hold that position until 1855, when the Birkenhead Docks were transferred to the Liverpool Corporation. In 1857, a Bill was brought in to change the trust; the result was the passing of the Consolidation Act of 1858, appointing the Mersey Docks and Harbour Board—which has since managed the docks on both sides of the river. Under that Act, the Board was constituted of twenty-eight members—twenty-four being elected by the dock ratepayers and four nominated by Government. Mr. Laird was asked to become a nominee member of the newly-formed Board—a post he accepted and held till his death. He also took an active part in the local affairs of the township, and was one of the first Commissioners under the Act of 1833.

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In 1861 Birkenhead and the adjoining townships were made into a Parliamentary Borough, and Mr. Laird was elected to represent it, and continued to do so until his death. He consistently urged on the Government the advisability of building our ships entirely of iron, and of equipping a fleet of small and powerful gunboats for home service. Mr. Laird's name was intimately associated with an important measure—the Chain Cable and Anchors Bill, which he introduced in 1863, and after a great deal of hard work got passed into law.

In return for the honourable confidence which Birkenhead placed in him, Mr. Laird bestowed several valuable benefactions on it. His most valuable gifts to the Borough were the Birkenhead Borough Hospital, a model institution of its kind, the foundation of which was laid 24th November, 1862, by the late Marquis of Westminster; and the Birkenhead School of Art, formally opened by the present Earl of Derby, September 27th, 1871. They are lasting monuments to the liberality and sound judgment of the first Member for Birkenhead.

He had been for many years a Magistrate and Deputy Lieutenant for Cheshire, a Trustee of the River Weaver, and a Member of the Council of the National Rifle Association. He assisted in the formation of the Institution of Naval Architects, of which he was one of the first Vice-Presidents.

During the last few weeks of the Session of 1874 Mr. Laird had to be excused from attendance in Parliament owing to ill health—there was a slight improvement on his return home, but his illness gradually assumed a more serious character, and on the 29th October, 1874, he died, in his 70th year.

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MEMOIR OF THE LATE JOHN GRANTHAM,*

Member of Council of the Institution of Naval Architects.

Mr. John Grantham, the second son of the late Mr. John Grantham, who was for several years engaged under the late Mr. Rennie in surveying many great works both in England and Ireland, was born at Croydon, in 1809. After leaving school, he was engaged with his father in surveying various lines of railway then projected in England, some of which were eventually carried out. He also assisted in the establishment of steam vessels and an improved system of navigation on the canals between Dublin and Limerick, and in the employment of steam on the River Shannon, which system was subsequently taken up by the City of Dublin Steam Packet Company, and continued until the competition of railways diverted the traffic. Upon leaving Ireland, he, on the introduction of the late Mr. Charles Wye Williams, Assoc. Inst. C.E., with whom he resided in Liverpool, joined the late firm of Messrs. Mather, Dixon & Co., of which he was subsequently manager and partner. In that establishment were constructed large mechanical works, such as marine engines, locomotives, sugar-mills, and nearly every kind of machinery. In the year 1830 he gained the prize offered by the London and North-Western Railway Company for a design for drawing up, by means of stationary engines, the passenger carriages from Lime Street to Edge Hill Station, Liverpool, which engines are still at work for some purposes, though locomotive power has generally superseded them. Mr. Grantham was one of the founders of the Polytechnic Society at Liverpool, and continued an Honorary Member till his death.

The firm of Messrs. Mather, Dixon & Co. having ceased to carry on business, he began practice on his own account, at Liverpool, as a naval architect and consulting engineer, and planned and executed several of the largest iron sailing and steam ships then employed in navigation, such as the *Sarah Sands*, *Pacific*, *Antelope*, *Empress Eugénie*, &c. He was engineer to the Whitehaven Steam Ship Company and other companies, for whom he constructed vessels for Australia and Egypt. He took out several patents for screw-propellers, which were then being introduced, and invented a system of sheathing

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iron-built ships with copper, which was afterwards employed by the Government, but without recognition or compensation. He held, for some years, the appointment of Surveyor of Passenger Steam Ships at Liverpool, under the Admiralty, and subsequently under the Board of Trade.

In 1859 he left Liverpool for London, and was largely engaged in arbitrations and consultations in cases connected with insurance and casualties of the mercantile marine, and relating to the construction of vessels. He designed a fleet of steam colliers, which ply between London and the North of England. In connection with his brother, he, in 1860, became Engineer of the Northern Railway of Buenos Ayres; and, in 1863, planned and executed the first tramway in Copenhagen, which is now working with success.

The latter part of his life was much occupied in the invention and perfection of a steam tramway car, which has been successfully tried, and for which he held a patent; but, as the law of this country prohibits the use of steam carriages on public roads, except under such restrictions as to render their general employment impracticable, it has only hitherto been worked experimentally. In foreign countries, however, where no such impediments obtain, a field appears to exist for the employment of this machine, which is noiseless, and does not differ in general construction from the ordinary tramway car, while it can be worked at one-half the cost of horse-power.

Mr. Grantham contributed many works to engineering literature—notably a book on *Iron Shipbuilding*,* illustrated with a copious atlas of drawings. This is a standard work on the subject, and is constantly referred to by Judges and Counsel when engaged in trials relating to iron ships, and by others for practical purposes connected with their construction. He also contributed Papers to several scientific societies. To the Institution of Civil Engineers he presented communications "On the Stationary Engines at the New "Tunnel on the Liverpool and Manchester Railway,"† at Edge Hill; an "Account of "some Experiments on a Vessel called the *Liverpool Screw*,"‡ which he constructed; a "Description of the *Vanguard* iron Steam Vessel, after being ashore on the rocks in the "Cove of Cork;"§ "Description of the *Sarah Sands*, and other Steam Vessels, fitted "with Direct-acting Engines and Screw-propellers, without Intermediate Gearing;"‖ and "Ocean Steam Navigation, with a View to its further Development,"¶ which last embraced the most important features of an extended view of steam communication by sea, comparing the working of several vessels as to speed, expenditure of fuel per

* Vide *Iron Shipbuilding: with Practical Illustrations.* 8vo. 4to. Atlas of Plates. London, 1858.
† Vide *Minutes of Proceedings of the Institution of Civil Engineers*, Vol. I. (1841), p. 146.
‡ *Ibid*, Vol. III., p. 71. § *Ibid*, Vol. VI., p. 283. ‖ *Ibid*, Vol. IV., p. 302. ¶ *Ibid*, Vol. XXIX., p. 126.

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indicated horse-power, and discussing the bearing of the opening of the Suez Canal on ocean steam navigation. For this Paper he received a Telford Premium of Books.

Mr. Grantham was one of the founders of the Institution of Naval Architects, in January, 1860; he was placed on the Council, and remained there until his death. He communicated several Papers to the Institution, and took an active part in its management and proceeedings.

Mr. Grantham was elected an Associate of the Institution of Civil Engineers on the 11th of February, 1840, and was transferred to the class of Member on the 29th of November, 1864. He latterly resided at Croydon, where he died on the 10th of July, 1874, at the age of sixty-five, deeply regretted by a large circle of friends, and universally respected for his exertions in support of the charitable and educational institutions of his native town.

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MEMOIR OF THE LATE HENRY D. P. CUNNINGHAM, R.N.,

Associate of the Institution of Naval Architects.

Mr. Henry Duncan P. Cunningham, well known as the inventor of the "Self-reefing "Topsail," was the second son of the late Dr. John Cunningham, R.N. He entered the Royal Navy on board the *Donegal*, 78, in 1830, and served afterwards in the *Pallas*, 42, where he gained early distinction by undertaking single-handed the dangerous task of surveying the defences of the Dardanelles, of which he executed detailed drawings for the information of Government.

Changing the executive for the civil line in 1835, he qualified for the rank of Paymaster, and was in September, 1838, appointed to the flagship at the Nore. He subsequently served under Sir William Parker and took part in the various operations conducted by that officer on the coast of China. In the attack on the enemy's entrenched camp on the heights of Segoan, 15th March, 1842, he was "one of the "foremost in the assault," and displayed conduct so spirited as to obtain for him mention for conspicuous gallantry in the despatches of Sir W. Parker and Sir Hugh Gough, as well as in a special letter written by the former to the Admiralty. He was also present in the attacks upon Chapoo, the batteries of Woosung, and the town of Chin-Kiang-Foo, and at the pacification of Nankin. During the latter part of these proceedings he was borne as Supernumerary Paymaster of the *Cornwallis*.

In August, 1845, he was nominated Secretary in the *President*, 50, to Admiral J. R. Dacres, at the Cape of Good Hope, where he arrived at the outbreak of the Kaffir War.

In 1848 he served in the boats engaged in the attack upon a fortified position in the Angoza River, again procuring special mention in the despatches. About the same period he took a prominent part in negociations with Queen Ranavalona of Madagascar, and made himself acquainted with the language of the country for the express purpose of conducting a treaty with that personage. In fact his knowledge of the political affairs and history both of Madagascar and of the Comoro Islands was such as to induce the Commander-in-Chief to bring it to the particular notice of Government.

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Although so active a life gave few opportunities for study Mr. Cunningham gave early proof of his remarkable mechanical abilities, and devoted much attention to engineering problems. Among his numerous inventions were, an "Eccentric Paddle-"wheel with an entire shaft," a "Reefing Paddle-wheel," his "Four-way Port Steam "Valves," a "Direct-action Steam Engine with long connecting rod," a "Lifeboat "Carriage," a "Lifeboat and Atmospheric Gun Carriage." For his "Lifeboat Carriage" originally designed for the life surf boat of Table Bay, he was presented with the silver medal of the Society of Arts. Of those connected with ordnance may be mentioned, "Chain-traversing Gear," "Endless Chain Running-in-and-out Gear," "Overhead Shot "Railways," "Shot Carriages, Slings, and Racks," and many others.

The most important of his inventions, and that for which he was most widely known, was his system of "Self-reefing Topsails." Early in his naval career he had been much impressed by witnessing one of those terrible accidents which were in former days unhappily by no means rare, and by which a fine young seaman lost his life. Setting before himself the task of remedying the defects of the old and cumbrous method of reefing topsails by devising means for reducing sail without the assistance of men aloft, he succeeded after many trials in perfecting his system of reefing topsails from the deck, by which the amount of sail spread could be diminished or increased without the intervention of a single man aloft, by the simple act of raising or lowering the yard to which the sail was bent and round which it rolled.

This admirable invention met with immediate and widespread recognition, thousands of vessels of all nations being fitted with it. It marked, in fact, a new era of improvement in the fitting and rigging of ships, and gave the first impulse to the many valuable devices for economising labour which have since been made.

The mercantile marine hailed it at once as the solution of an old and difficult problem, increasing in a high degree the ease and safety of manœuvring ships, and effecting an enormous saving both of time and labour; whilst the extent to which it diminished the discomforts and dangers of a seafaring life, gained for it, amongst seamen, the honourable title of the "Sailor's Friend." His system of "continuous "braces and brace machines" and other numerous inventions have also greatly added to simplicity and efficiency in performing the heavy labour connected with working ships' yards and sails.

Anticipating with rare foresight the vast increase in size and weight of ordnance, due to the general introduction of rifling, he was the first to seek, in other means than mere manual labour, the force necessary to deal with great weights, and devised many

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methods of working heavy guns and projectiles. He greatly assisted the late Captain Cowper Coles, R.N., in providing means for working the turrets of the *Royal Sovereign*, and by his application of steam to all the movements of heavy guns, he provided an ingenious and effective means of dealing with even the heaviest *matériel.* His chain-traversing gear, first fitted in 1866 to a 23-ton gun mounted in Southsea Castle, is pre-eminently simple and efficacious, a tribute to its practical value being found in the fact that it was subsequently adopted by the German Government for all heavy ordnance for coast defence.

Mr. Cunningham was an Associate of the Institution of Naval Architects from its commencement, and contributed valuable Papers on "The Rig and Sails of Steam Ships "of War," "Working Ships' Yards," "The Application of Steam Power to the Working "of Heavy Guns," and "The Mechanical Methods of Training and Working Heavy "Naval Guns." He was a Medallist and Juror of the International Exhibition of 1862, and a member of numerous Scientific Societies. He took a warm interest in the formation of the Rifle Volunteers, and was one of the "Eleven" who first gave their names for enrolment. He was the means of forming in 1859 the 6th Hants (Gosport) Rifles, but subsequently transferred his interest to the Artillery Volunteers; and the corps to which he was attached as Major was indebted to him for much valuable information and instruction which he was ever ready to impart. He was a Justice of the Peace for the County of Hants, occupying a seat on the Bench for fourteen years. He was also one of the earliest promoters of the Sailors' Home movement, and other institutions of a like character.

He died at Bury House, Gosport, on the 19th January, 1875.

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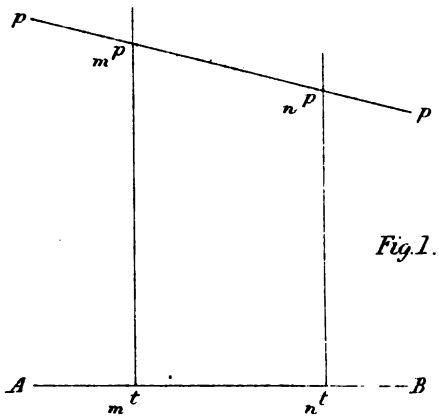

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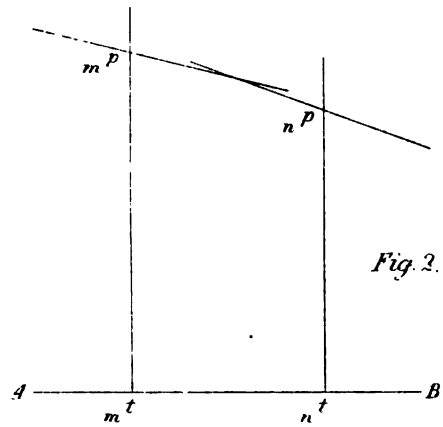

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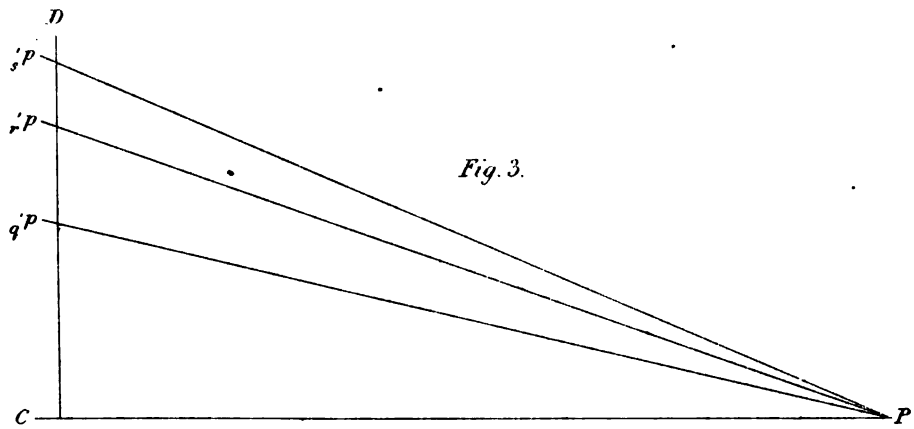

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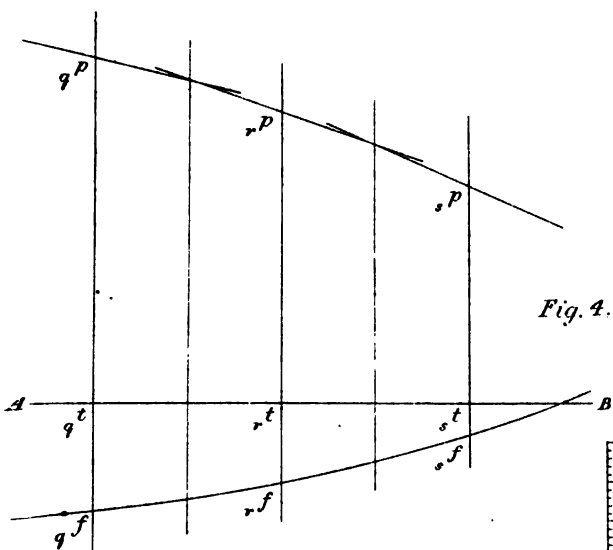

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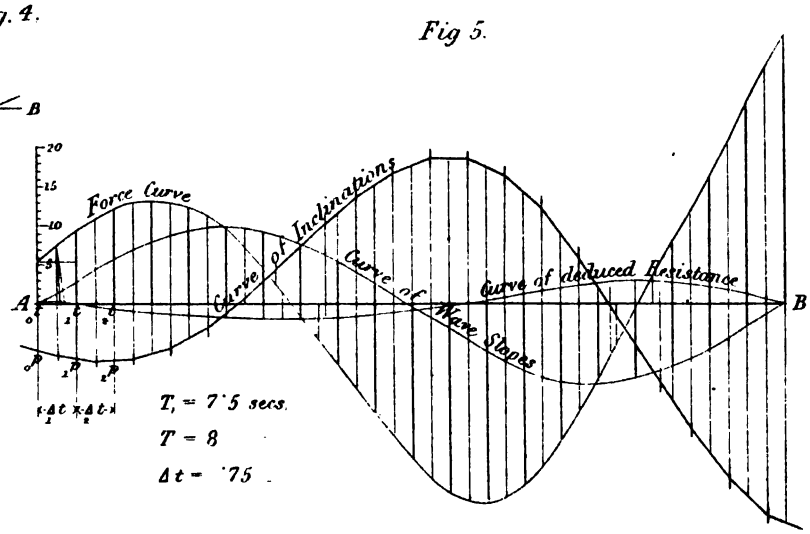

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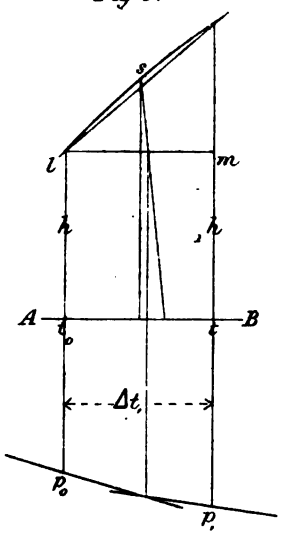
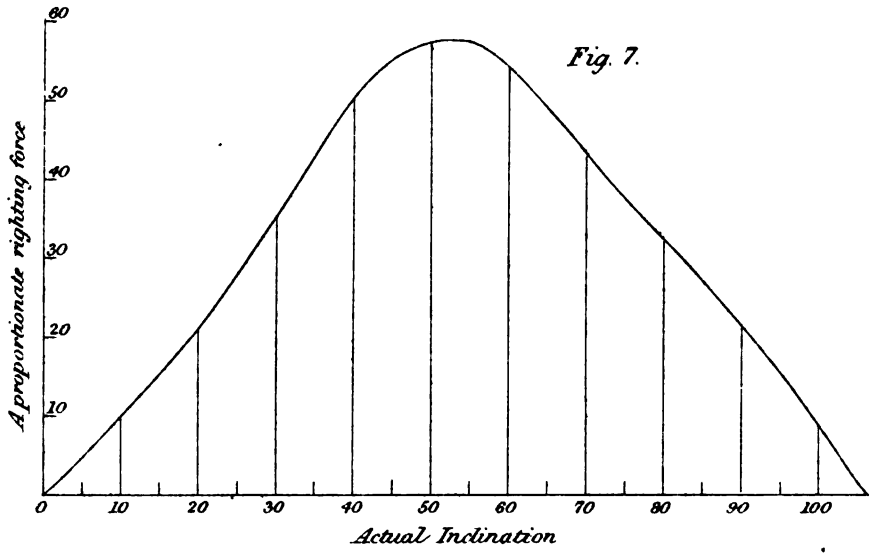
Fig. 6.



Curve of stability

Fig. 7.



Extinction Diagram of H.M.S. Inconstant.

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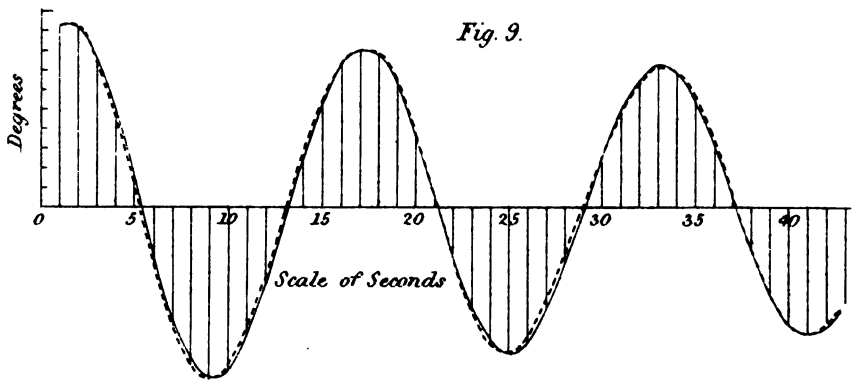

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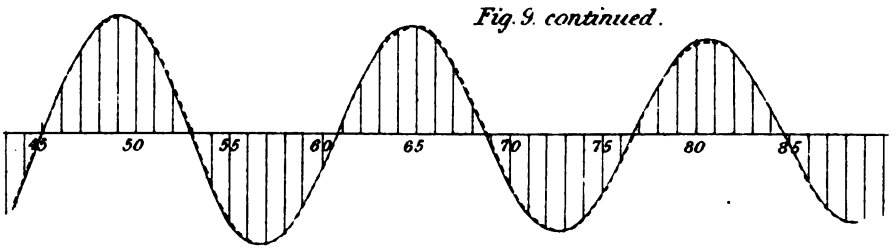

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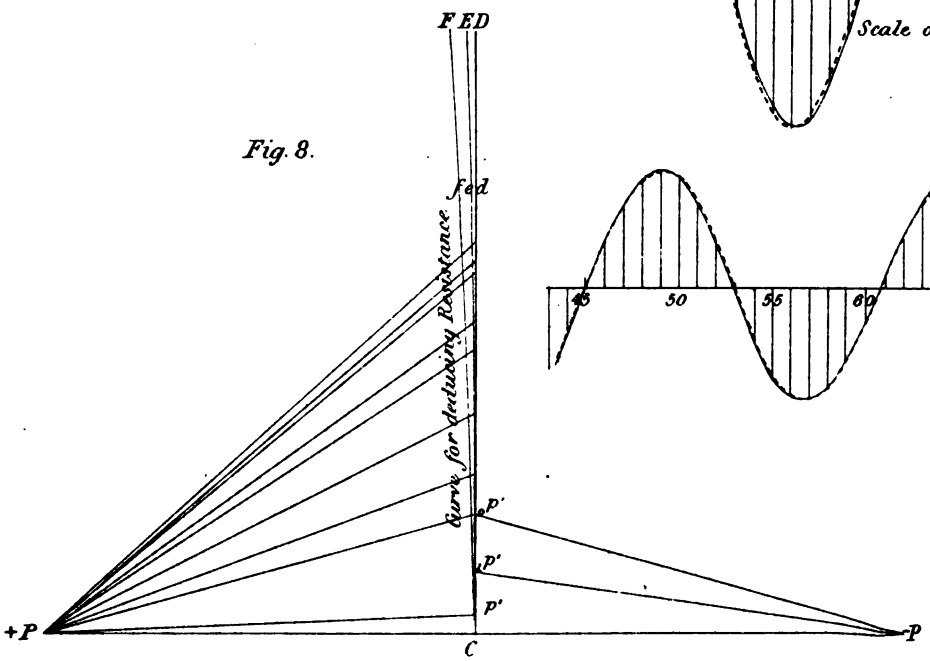

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To illustrate Mr. W. Froude's Paper on The Graphic Integration on the Equation of a Ship's Rolling including the Effect of Resistance.

Extinction Diagram of H.M.S. Devastation.

Fig. 10.

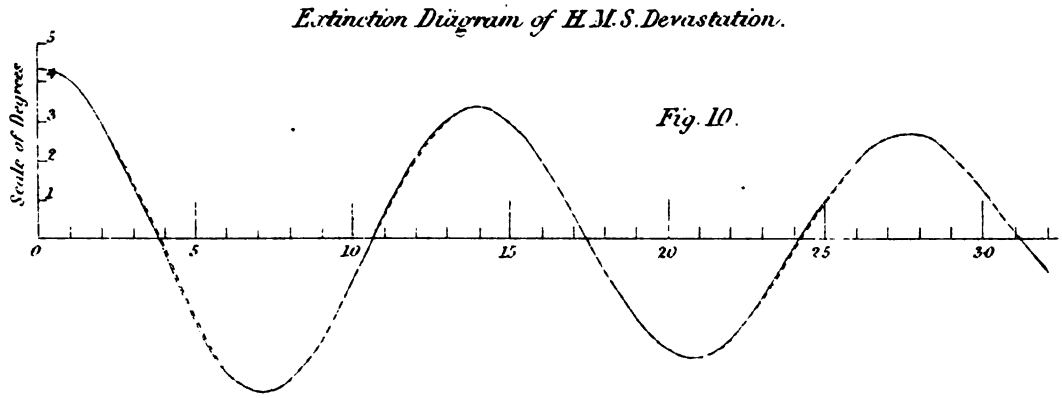


Fig. 10. continued

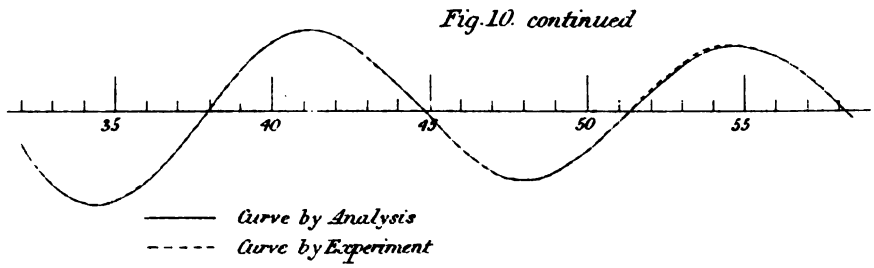
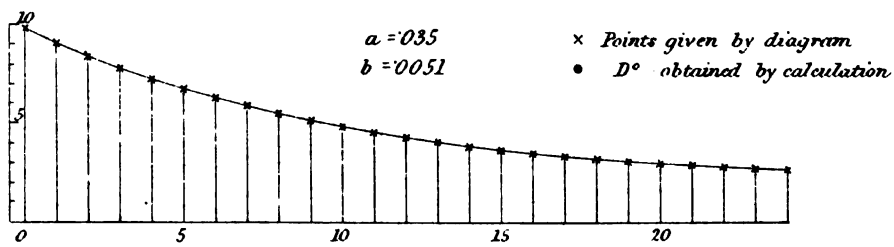


Fig. 11.

Curve of extinction of H.M.S. Inconstant.



General Differential Equation of a Curve of Extinction $\frac{d\theta}{dn} = a\theta + b\theta^2$

Integral $n = \frac{1}{a} \log \frac{b+a}{b+a\theta}$

Fig. 12.

Curve of Extinction of H.M.S. Devastation.

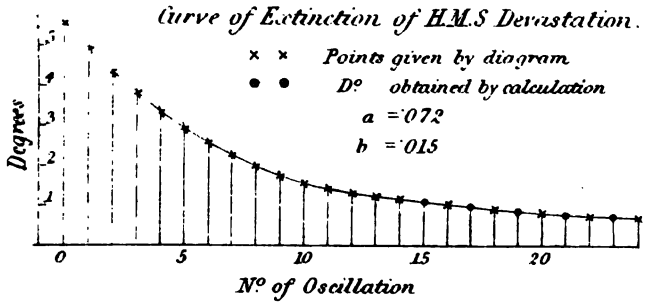
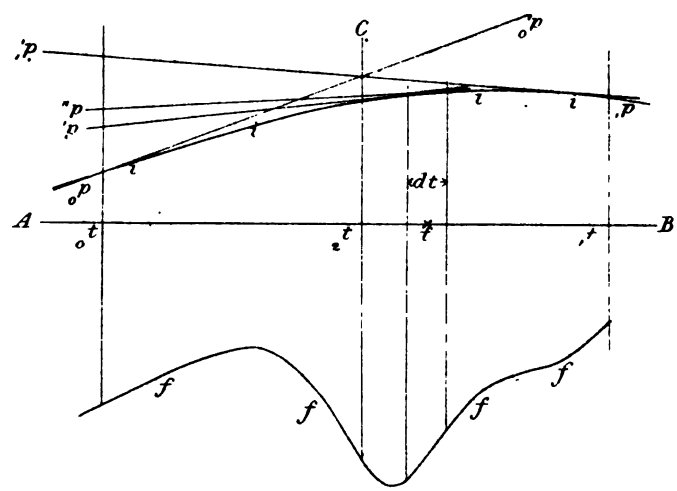


Fig. 13.



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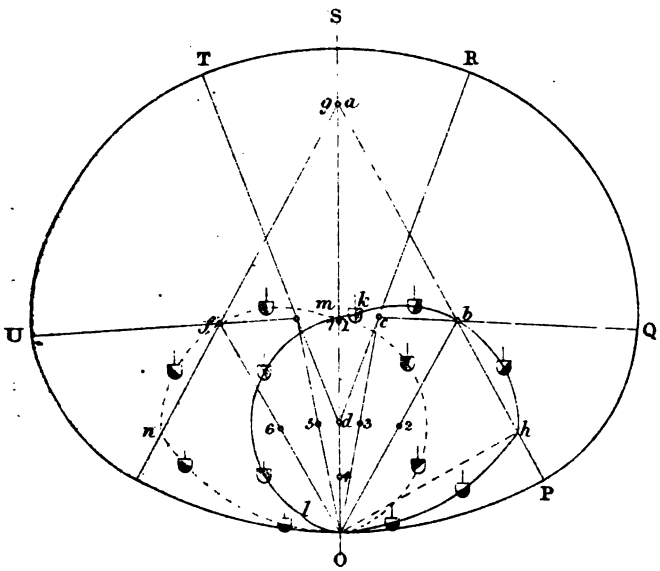
To illustrate Mr. J. Mc Farlane Gray's Paper on Polar Diagrams of Stability

Fig. 1.



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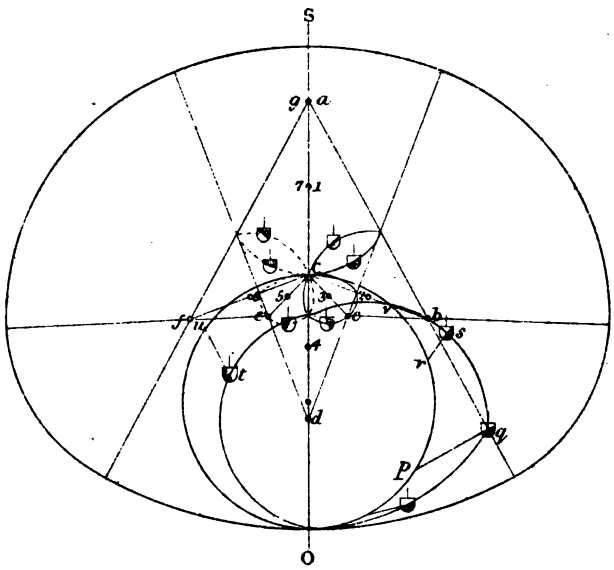
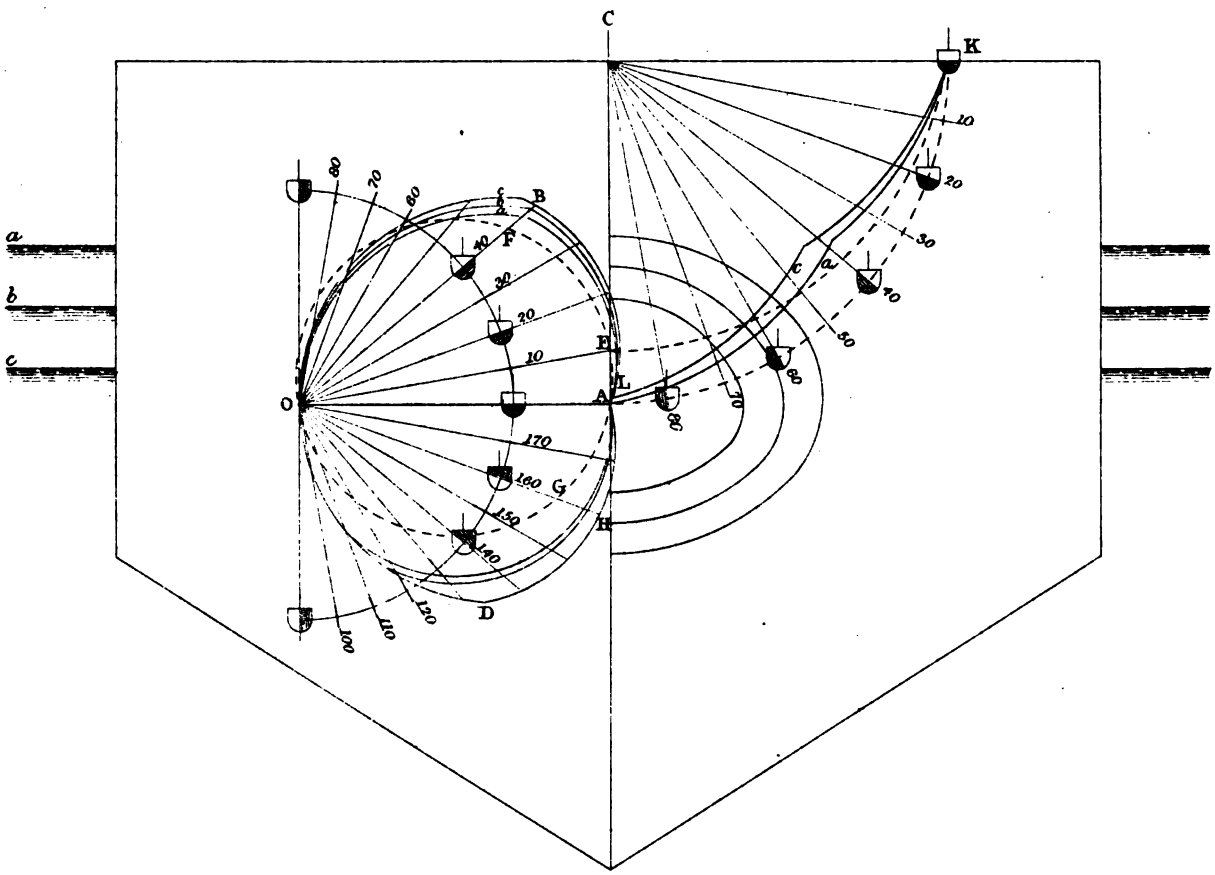


Fig. 3.



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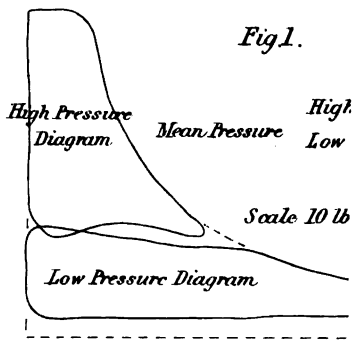

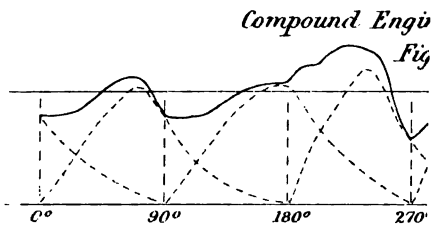

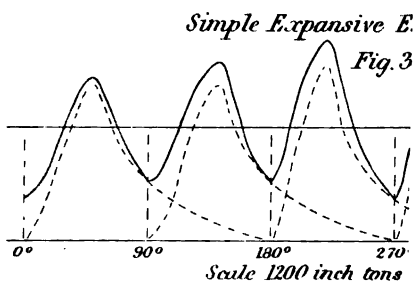

Figs. 2 and 3. Diagrams of twisting moments;

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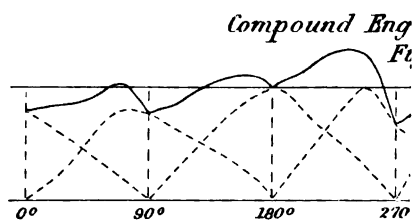
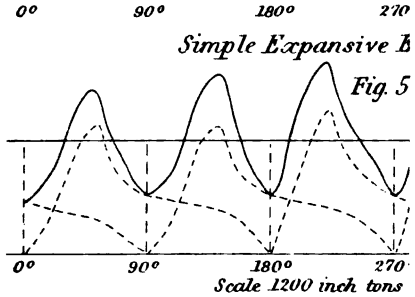
Maximum twisting moments in inch t
Mean
Ratio of $\frac{\text{maximum}}{\text{mean}}$





Figs. 4 and 5. Diagrams of twisting moments; in

Maximum twisting moments in inch ton
Mean
Ratio of $\frac{\text{maximum}}{\text{mean}}$

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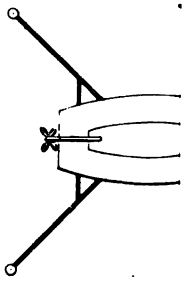
Fu



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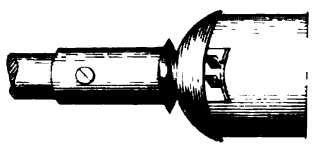

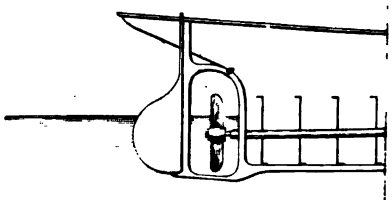

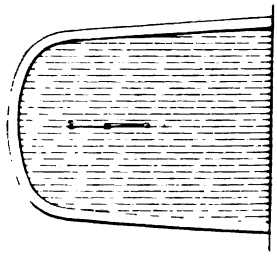

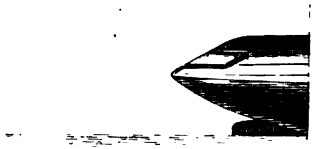

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To illustrate The Rt. Hon. Viscount Bury's Paper on a New Binnacle Indicator.

Fig. 1.

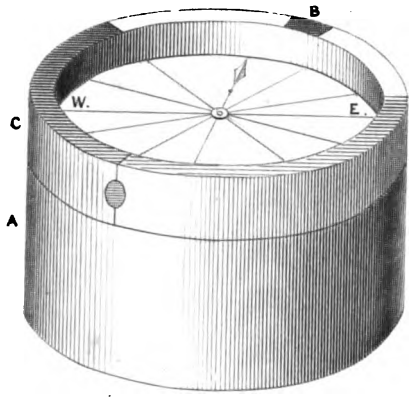


Fig. 2.

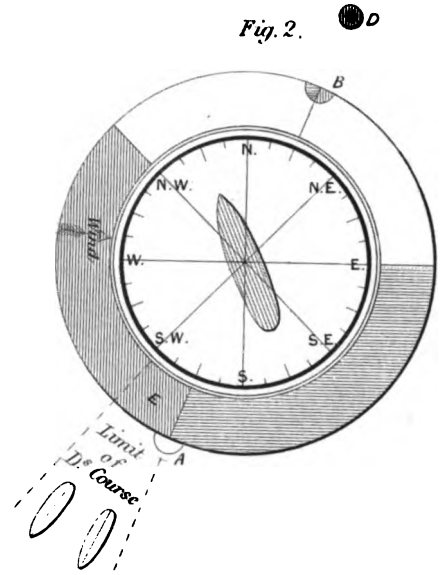


Fig. 3.

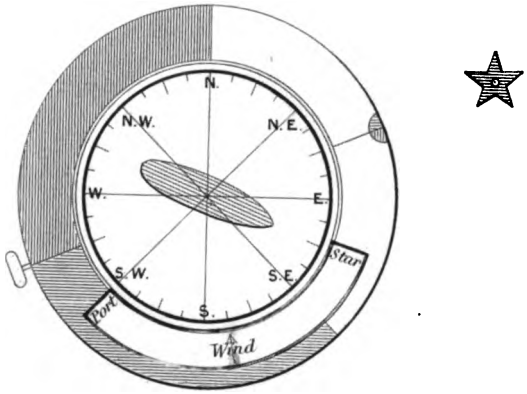


Fig. 4.

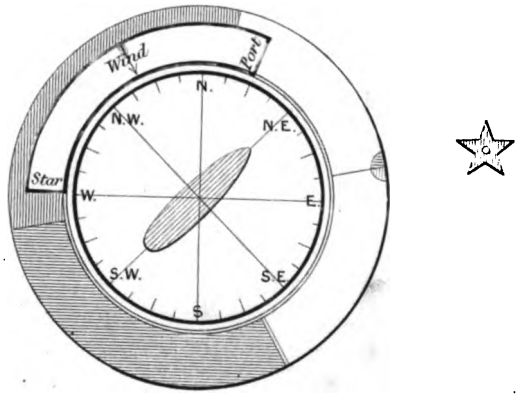
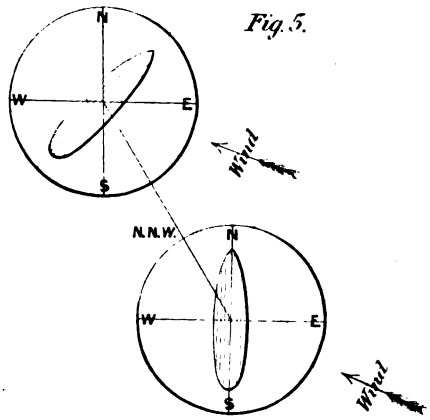


Fig. 5.



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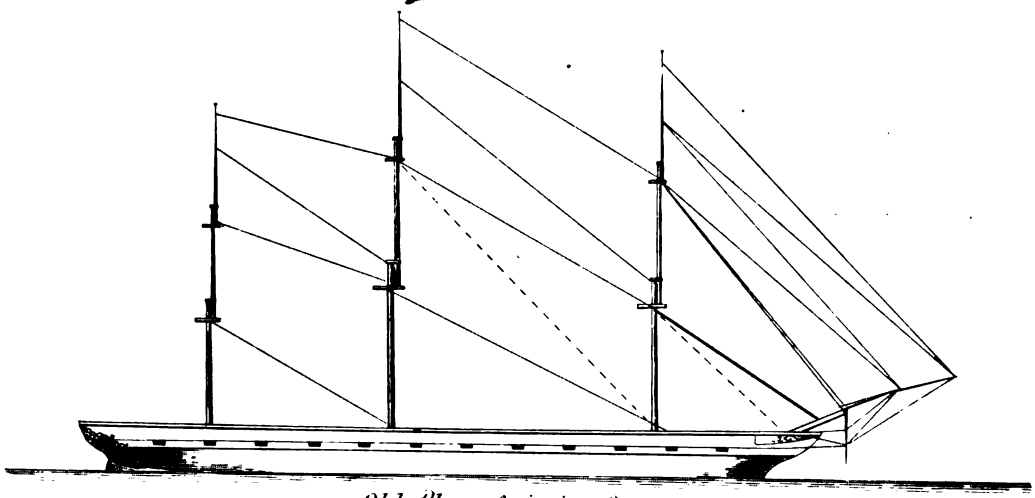
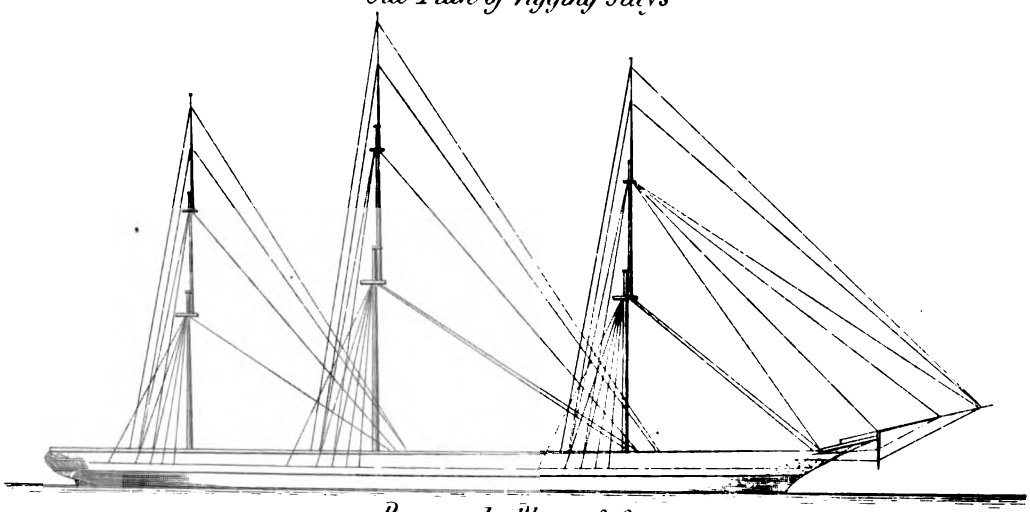
To illustrate Mr. W. Fleming's Paper On the Rig of Ships



Old Plan of rigging Stays



Proposed Plan of Stays.

To illustrate Mr. W. Forbes' Paper On a New Rig for Ships

Fig. 2.

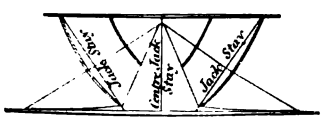


Fig. 3.

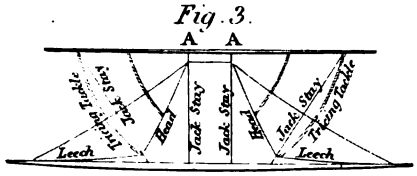


Fig. 4.

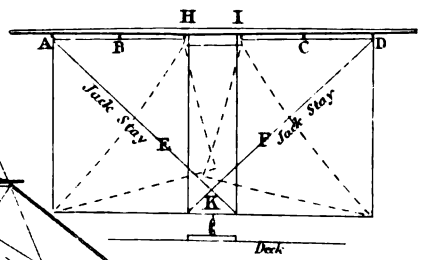
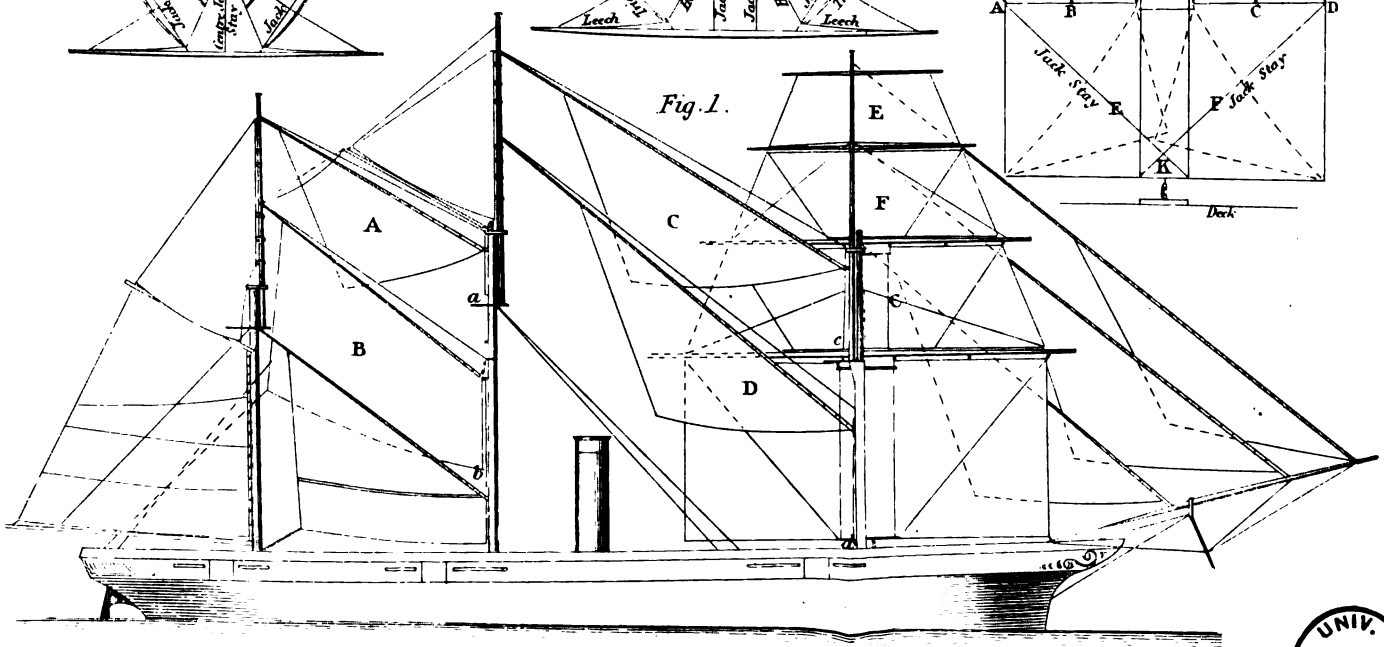


Fig. 1.



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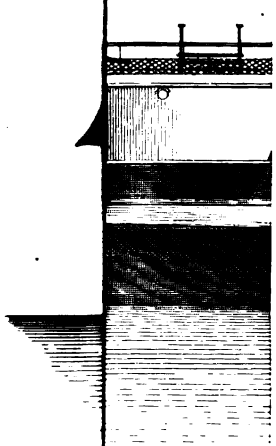
Steamship.



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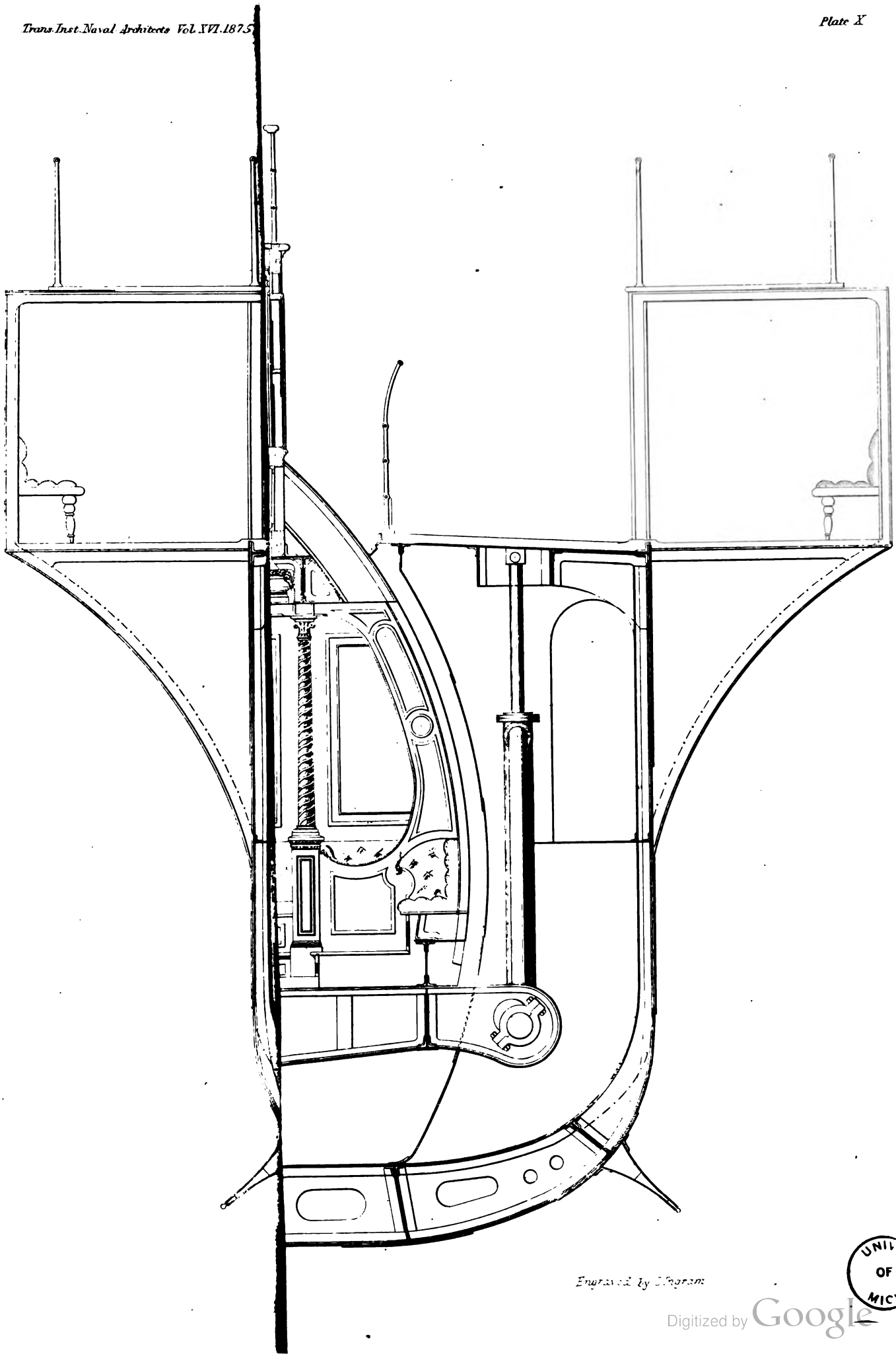

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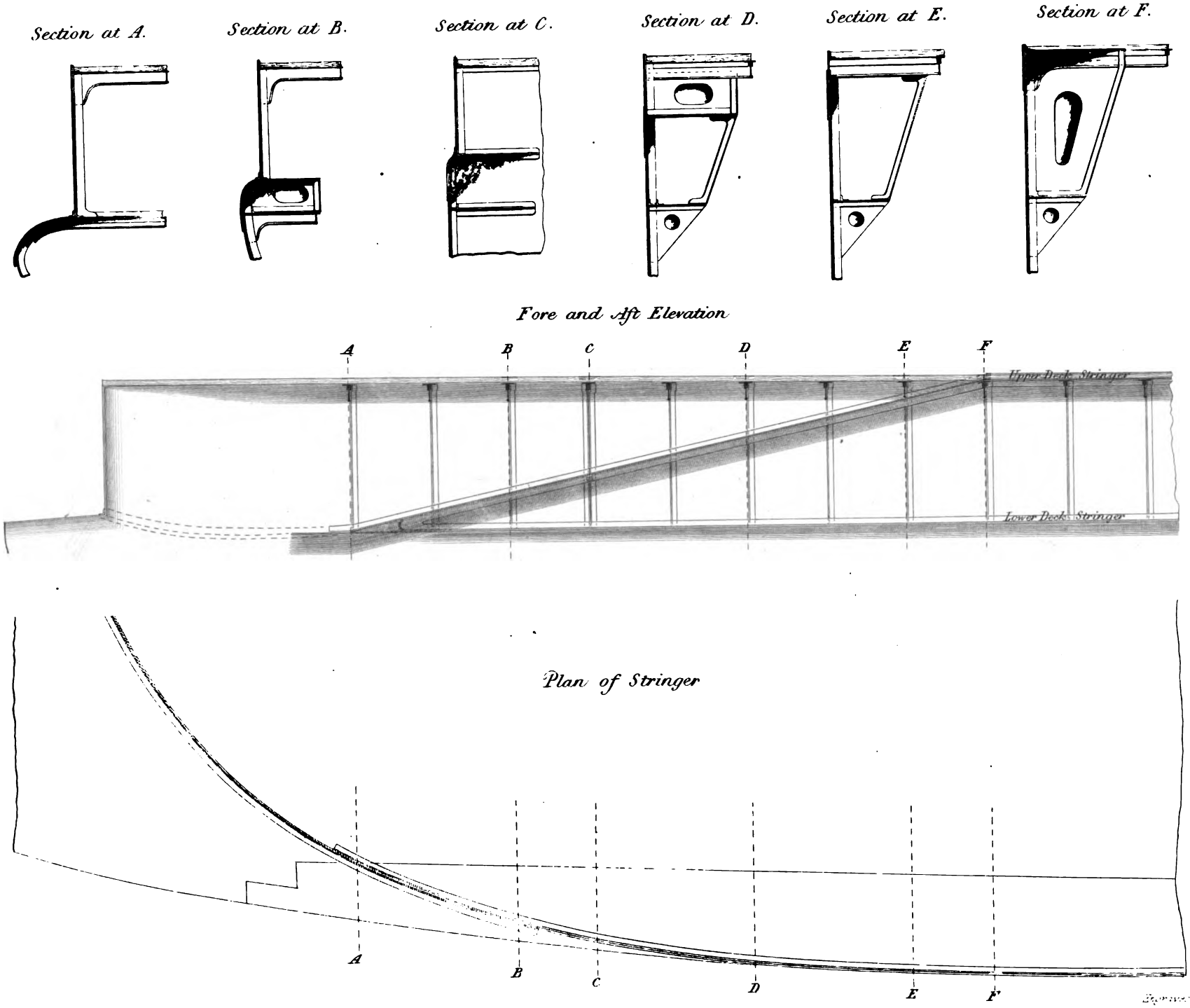
To illustrate Mr. E. J. Reed's Paper On the Bessemer Steamship



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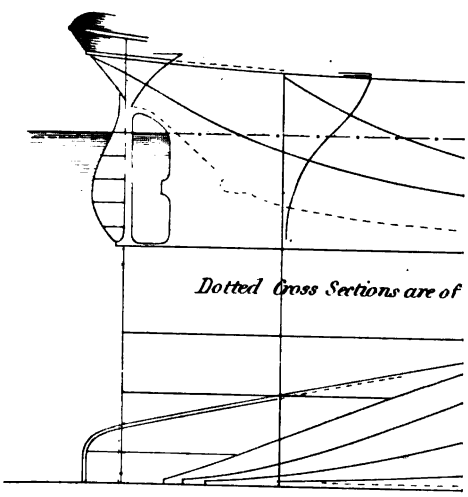
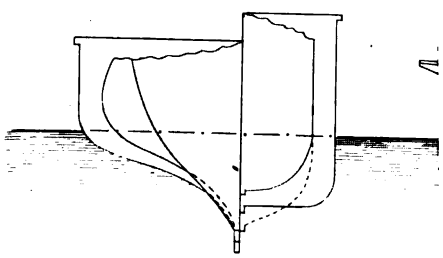


Fig. 7.
Combined Displacement_Vertical



Comparison when light

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